Cardiff School of Sport

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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT CONDITIONING, REHABILITATION AND MASSAGE

THE EFFECTS OF ACUTE CAFFEINE CONSUMPTION ON JUMP SQUAT PEAK POWER OUTPUT

(Dissertation submitted under the discipline of SCRAM)

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THE EFFECTS OF ACUTE CAFFEINE CONSUMPTION ON JUMP SQUAT PEAK POWER OUTPUT

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<u>**CONTENTS**</u>

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

Appendices

LIST OF TABLES

LIST OF FIGURES

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Abstract

The purpose of this study was to investigate the effects of acute caffeine consumption on jump squat peak power output. Eight resistance-trained university sports students (n=8 21.4 ± 1.2 years, 87.1 ± 9.8 kg and 179.3 ± 4.4cm) participated in the study, where they completed two testing sessions; a placebo beverage trial and a caffeine beverage trial, separated by one weeks rest. The study employed a double blind cross-over protocol so participants were unaware of the order of supplement consumption prior to testing. The caffeine trial involved a 3 $mg \cdot kg^{-1}$ body mass (BM) dose of caffeine being administered 30 min prior to one of the testing sessions where anaerobic performance was measured. The placebo trial followed the same testing procedure with a placebo beverage consumed prior to testing rather than a caffeine beverage. Seven sets of one unloaded barbell jump squats were completed in each testing session; each set was performed with maximal effort with power output of each set recorded, with 5 mins of rest in between each set. Caffeine was found to significantly increase total work completed in each testing session for participants (caffeine = 15533W ± 2165.4 Watts vs. placebo = 15033 ± 2119.1 Watts, $P<0.05$) furthermore, caffeine also significantly increased the mean power output of participants in each testing session (caffeine = 2219 ± 309.3 Watts vs. placebo 2147.6 ± 302.7 Watts, $P<0.05$). However, caffeine was found to not significantly increase peak power output in the jump squat exercise over seven sets (caffeine = 2336.3 ± 305.6 Watts vs. placebo = 2256.5 ± 374.9 Watts $P>0.05$). A caffeine dose of 3 $mg \cdot kg^{-1}$ body mass (BM) significantly increased anaerobic performance during seven sets of jumps squats, more work was completed and mean power output during each set was increased, however caffeine had no significant effect on peak power output values.

CHAPTER 1

INTRODUCTION

1.0 Introduction

Caffeine is a readily available and socially accepted substance (Antonio., 2004; Beck *et al.,* 2006; Del Coso *et al.,* 2012.), with around 90% of adults consuming it in their everyday lives (Astorino and Roberson., 2010.). Caffeine is found naturally in the leaves, fruits or seeds of various plants and is in a variety of food and beverages such as chocolate, tea, coffee, energy drinks and also some dietary supplements and over the counter medicines (Woolf *et al.,* 2009; Astorino and Roberson., 2010; Del Coso *et a.l,* 2012.). Caffeine is not illegal in competition and in 2004 was removed from the world anti-doping agencies (WADA) list of prohibited substances (Woolf *et al.,* 2008.). However it still remains a monitored substance within competition to check for misuse, with any recorded urinary levels of >15 micrograms/ml after competition deemed illegal, making athletes conscious of their caffeine intake prior and during competition (Woolf *et al.,* 2008.).

Athletes at all levels of sports are always looking for methods to enhance performance and gain an edge over their opposition. Caffeine has long been a popular ergogenic aid for athletes worldwide (Doherty and Smith., 2004; Desbrow and Leveritt., 2006; Woolf *et al.,* 2009.), in particularly endurance athletes (Graham *et al.,* 1998; Bell and McClellan*.,* 2003; Conway *et al.,* 2003; Bridge and Jones., 2006.); with caffeine found to improve exercise performance and endurance by enhancing free-fatty acid oxidation and glycogen sparing, primarily thought to occur by an amplified adrenaline output (Costill *et al.,* 1978; Davis and Green., 2009.). It is also well known that caffeine stimulates the central nervous system (CNS), increasing arousal, wakefulness, alertness, focus and also reducing fatigue (Lieberman *et al.,* 2002; van Duinen *et al.,* 2005; Woolf *et al.,* 2009; Astorino and Roberson., 2010.). However the exact mechanism by which caffeine enhances anaerobic performance remains unclear (Beck *et al.,* 2006.).

Caffeine is completely absorbed within the stomach and small intestine 45 minutes after ingestion and has a half-life of approximately 3 – 4 hours in the body (Graham., 2001.). The literature suggests that ergogenic doses of caffeine ranging from 2 to 9 mg-kg^{-1} of BM can enhance high intensity and team sport performance (Stuart *et al.,* 2005; Schneiker *et al.,* 2006; Woolf *et al.,* 2008.) and endurance performance (Bell and McClellan*.,* 2003; Conway *et al.,* 2003; Bridge and Jones., 2006; McNaughton *et* *al.,* 2008.). Caffeine is a safe substance but high doses can increase the chances of unwanted side effects such as anxiety, restlessness, and headaches which can impair performance (Astorino and Roberson., 2010).

The literature investigating caffeine's effect on anaerobic performance is vast with numerous studies concentrating on the Wingate test as a measure for lower body anaerobic power output, and the bench press repetitions to failure as a measure of upper body muscular endurance and strength. No study yet has investigated caffeine's effect on anaerobic performance and power output using the jump squat.

It is established that caffeine benefits endurance performance and exhaustive exercise, but the literature around anaerobic performance and power output is limited and somewhat unclear (Davis & Green., 2009). Many athletes from individual and team sport environments regularly train to improve and develop their lower body power and anaerobic capabilities, to improve their performance and gain a physical edge. Therefore a definite conclusion for caffeine's ergogenic effect on anaerobic performance and power output is required with many sports such as rugby, hockey and football requiring a high level of lower body power and anaerobic capabilities.

Therefore, this study will aim to investigate the effect that acute caffeine supplementation has on jump squat power output within resistance trained male university sports students. The aim of the study is to confirm that after acute caffeine ingestion peak power output should increase when compared to the placebo trial. Also a further aim of the study is to investigate that caffeine ingestion will increase average jump squat power output and total work completed by the participants, showing caffeine can decrease fatigue.

The Hypothesis (H_I) of the study states that after ingesting a 3 mg-kg^{-1} BM dose of caffeine participants would see an anaerobic performance increase in peak power output, average power output and total work completed, when compared to the placebo trial.

The Null Hypothesis (H_o) of the study states that after ingesting a 3 mg-kg^{-1} body mass dose of caffeine participants would not see an anaerobic performance increase in peak power output, average power output and total work completed, when compared to the placebo trial.

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

2.1 Pre-Workout Drinks Overview

Pre-workout Energy drinks have grown in popularity and become common place in athletes and fitness enthusiasts training routines and also competition (Gonzalez *et al.,* 2011). It has been found that up to 70% of adolescents and young adults have reported using at least one nutritional supplement, with high-energy drinks among the most popular. Studies suggest that 30% of this population regularly consume energy drinks and is second to multivitamins in regards to the type of supplement used (Froiland *et al.,* 2004; Hoffman *et al.,* 2008; Alves and Lima., 2009.). Pre-workout energy drinks are used by both aerobic and anaerobic athletes due to their potential ergogenic effects and have started to attract the attention of many competitive and recreational athletes as a legal ergogenic aid (Sokmen *et al*., 2008). Pre-workout energy drinks are a relatively new category of beverage and contain the basic active ingredient caffeine in amounts that exceed those in soft drinks and are similar to the concentrations found in coffee (Mandel., 2002; Hoffman., 2010.). Caffeine is a natural alkaloid present in the leaves, fruits and seeds of various plants; it can also be artificially synthesized in the laboratory (Del Coso *et al.,* 2012.). The dual origin of caffeine has turned it into the most commonly ingested drug in the world, as it is found in a variety of foods and beverages such as chocolate, tea, coffee, cola drinks, energy drinks, dietary supplements and over the counter medications (Klepacki., 2010; Del Coso *et al.,* 2012.). Caffeine's use as an ergogenic aid will not decline any time soon due to it being inexpensive, medically safe, socially acceptable and legal (Sinclair and Geinger., 2000.).

2.2 Caffeine as an Ergogenic Aid

Caffeine has been used as an ergogenic aid to sports performance for more than a century, as it is thought to have multiple beneficial physiological effects on the body and it is this reason it has been widely studied by exercise scientists (Keisler and Armsey., 2006.). From 1980 to 2003, it was included on the list of substances banned by the International Olympic Committee, with limits on urinary caffeine levels above which caffeine use would be deemed to be a doping offence. These levels were intended to discriminate the intake of large amounts of caffeine—typically, above 6–9 mg/kg of an athlete's body mass (Burke and Spriet., 2010.). Caffeine still remains a monitored substance for competitive athletes since; The World Anti-Doping Agency (WADA) removed it from its prohibited list in 2004 and added it to its monitoring program during competition. The WADA monitor caffeine levels during competition to check for misuse (Woolf *et al.*, 2008.). Ergogenic doses of caffeine usually range from 2 to 9 mg-kg of body weight, higher doses will typically elicit side effects such as anxiety, restlessness and headaches which may impair performance (Astorino and Roberson., 2010.). Caffeine needs to be ingested at least 45minutes before exercise for it to be completely absorbed by the stomach and small intestine, and then it's half-life in the body where it elicits physiological effects is approximately up to 3 – 4 hours (Graham., 2001). The majority of research on the ergogenic effects of caffeine have been on aerobic endurance and time to exhaustion, so more research needs to be conducted to look into caffeine's effect on anaerobic exercise.

2.3 Caffeine Research on Anaerobic Performance

Research surrounding caffeine's effect on anaerobic performance is mixed and has focused on Wingate/Sprint Cycling Power Output (Beck *et al*., 2006; Bidwell *et al.*, 2006; Greer *et al*., 2006; Lorino *et al*., 2006; Forbes *et al*., 2007; Hoffman *et al*., 2007; Williams *et al*., 2008; Woolf *et al*., 2008; Campbell *et al*., 2010.), short high intensity repeated sprints (Paton *et al*., 2001; Davis and Green., 2009; Gwacham and Wagner., 2012.) and bench press strength or muscular endurance (Beck *et al*., 2006; Forbes *et al*., 2007; Green *et al*., 2007; Astorino *et al*., 2008; Beck *et al*., 2008; Goldstein *et al*., 2010; Duncan and Oxford., 2011; Del Coso *et al*., 2012.).

2.3.1 Wingate/Sprint Cycling Power

The Wingate test is a widely accepted measure of power output and anaerobic capacity, it's that reason it is commonly employed when assessing ergogenic aids and anaerobic performance (Davis and Green., 2009). Previous research on the effects of caffeine on Wingate performance has conflicting results with some studies finding that caffeine does have an ergogenic effect on performance (Bidwell *et al*., 2006; Woolf *et al*., 2008.). However the majority of studies have found caffeine to have no effect on anaerobic performance in the Wingate test (Beck *et al*., 2006; Greer *et al*., 2006; Lorino *et al*., 2006; Forbes *et al*., 2007; Hoffman *et al*., 2007; Williams *et al.*, 2008; Campbell *et al.*, 2010.). Beck *et al.* (2006) found no significant difference in PPO when participants consumed caffeine and performed two 30-

second Wingate tests, compared with placebo. This study was large, involving 37 resistance trained male participants performing two Wingate tests. These findings were supported by Greer *et al.* (2006) who used a similar exercise protocol but on a smaller sample consisting of 18 active college males. Lorino *et al.* (2006) investigated caffeine's effect on a single 30 second Wingate test performed an hour after consumption and after a pro-agility run, this study agrees with the findings of Beck *et al.* (2006) and Greer *et al.* (2006). Furthermore (Forbes *et al*., 2007; Hoffman *et al*., 2007; Williams *et al*., 2008; Campbell *et al.*, 2010.) all investigated the effect of caffeine on anaerobic performance with results reporting no significant increase in PPO and MPO in the 30 second Wingate test protocol. Conversely Bidwell *et al.* (2006) and Woolf *et al.* (2008) both found caffeine to significantly increase PPO in the 30 second Wingate test compared to placebo. The reasons for this significant increase is unclear, with all other studies failing to find any significant increase in anaerobic power output, this highlights a need for further more in depth research into the area (Davis and Green., 2009.).

2.3.2 Short High Intensity Repeated Sprints

Short high intensity repeated sprints are sport specific and are often used to study the effects of caffeine on sprinting performance and agility (Davis and Green., 2009.). Previous research from Paton *et al.* (2001) found caffeine to have little effect on performance, 16 participants from team sport backgrounds such as hockey, rugby and football, performed 10 x 20metre sprints with 10 seconds rest between sprints. These sprints were completed after consuming either 6 $mg \cdot kg^{-1}$ BM of caffeine or placebo. However a potential problem was discussed in this study, there was possibly a lack of space towards the end of the 20 metre sprint which meant subjects had to decelerate earlier, which is likely to have impaired sprint times and mask any ergogenic effects of caffeine (Paton *et al*., 2001; Davis and Green., 2009.). However research by Stuart *et al.* (2005) found caffeine to increase performance of 7 rugby players in a sprint, agility and power circuit. Stuart *et al.* (2005) simulated a rugby game with the participants performing seven circuits in each 2 x 40minute half, with 10minutes half time rest after consuming 6 $mg \cdot kg^{-1}$ BM of caffeine or placebo. Sprint times throughout the trial were improved by the ingestion of caffeine, especially during the first half of the simulated game (Stuart *et al*., 2005; Davis and Green., 2009.). The findings of Paton *et al.* (2001) and Stuart *et al.* (2005) methods were slightly different thus producing conflicting findings, the distances used and rest times in both studies were different and this would affect the findings. A recent study by Gwacham and Wagner. (2012) backs up the findings of Paton *et al.* (2001), they looked at the acute effects of a caffeine-taurine energy drink on repeated sprint performance of 20 male American college football players. The study consisted of the participants consuming a caffeine supplement or placebo 60 minutes before performing six 35 metre sprints with 10 seconds of rest between sprints. Gwacham and Wagner found caffeine did not improve sprint performance or anaerobic power, however they believe the level of caffeine habituation could affect the ergogenic effects on performance.

2.3.3 Bench Press Strength-Power Performance

The majority of studies assessing caffeine as an ergogenic aid focus on testing lower body anaerobic capabilities and muscular endurance. However there are a few studies which assess upper body muscular endurance and maximal strength with the common method of using the bench press (Davis and Green., 2009.). The research again has conflicting results with studies finding caffeine to have no effect on bench press repetitions to failure and 1RM (Green *et al*,, 2007; Astorino *et al*., 2008; Beck *et al*., 2008.) and other studies finding caffeine does improve bench press repetitions to failure and 1RM (Beck *et al*., 2006; Forbes *et al*., 2007; Goldstein *et al*., 2010; Duncan and Oxford., 2011.). Previous research by Astorino *et al.* (2008) found acute caffeine to have no significant effect on muscular strength or endurance. Astorino *et al.* (2008) used 22 resistance trained male participants, who consumed a 6 $mg{\cdot}kg^{-1}$ BM caffeine supplement or placebo 1 hour before exercise in a double-blind crossover design, they then performed one-repetition maximum testing on the bench press, then using their 1RM score they performed bench press repetitions to failure at 60% of their 1RM, a problem with the study is how long rest they had in between the 1RM test and repetitions to failure, as this could have an effect on the results. Results from Beck *et al. (*2008) research, backs up the findings of Astorino *et al.* (2008), as they also found caffeine to have no significant effect on bench press strength. Beck *et al.* (2008) used 31 male participants, who consumed a 201 mg caffeine supplement or placebo 45 minutes prior to 1RM bench press testing. The results found caffeine to have no significant effect on bench press strength when compared to the placebo, however the participants used in this study were untrained to moderately trained individuals, this could effect the results as training status could effect the ergogenic responses to caffeine. However Beck *et al.* (2006) found caffeine to increase upper body strength compared to the placebo, 37 resistance trained male participants consumed a caffeine supplement or placebo 1 hour before completing 1RM bench press test. However a problem with this study is the dosage of caffeine the participants consumed is unclear, caffeine dosage ultimately effects any ergogenic effects on participants and this also makes it difficult for any future research to replicate this studies procedure or draw on the study for guidance on dosage levels. Forbes *et al.* (2007) found caffeine to significantly increase total bench press repetitions over 3 sets. 15 healthy young adult participants consumed 2 $mg{\cdot}kg^{-1}$ BM dose of caffeine Redbull supplement or non-caffeinated placebo 60 mins before performing 3 sets of bench press at 70% of 1RM to failure with 1 minute rest between sets. This study used a slightly different method to assess muscular endurance as the participants performed 3 sets of bench press to failure rather than 1 set that previous studies have used, by assessing 3 sets it's more reliable as 1 set to failure isn't likely to significantly assess ones muscular endurance. Also this testing method is relevant to readers as they are likely to perform 3 sets of bench press when they train in the gym so will be able to relate to the study. Goldstein *et al.* (2010) and Duncan and Oxford. (2011) further conclude that caffeine has a ergogenic effect on muscular endurance, both studies assess repetitions to failure of the bench press after consuming a caffeine supplement or placebo 60 minutes prior to testing. Research findings on bench press performance after caffeine supplementation is conflicting like all research on caffeine and anaerobic performance, however all studies have used different genders, ages, training status and caffeine dosage levels, making reviewing the literature difficult.

2.4 Training Status (trained vs un-trained)

There are mixed views surrounding the literature for caffeine's ergogenic effect on anaerobic performance, even more so when taking into account the training status of the participants used within the studies. Beck *et al.* (2008) conducted a study using 31 male untrained to moderately trained participants, they consumed a 201 mg caffeine supplement or placebo 45 minutes prior to 1RM bench press testing. They found caffeine to have no significant effect on bench press strength when compared to the placebo. Whereas an earlier study by Beck *et al.* (2006) used 37 resistance trained male participants to consume a caffeine supplement or placebo 1 hour before 1RM bench press testing. The results found that caffeine had an ergogenic effect on performance in the 1RM bench press testing of resistance trained males. It's well supported in the literature that caffeine has increased anaerobic performance in trained participants (Stuart *et al*., 2005; Beck *et al.*, 2006; Bidwell *et al*., 2006; Forbes *et al*., 2007; Woolf *et al.*, 2008; Goldstein *et al*., 2010; Duncan and Oxford., 2011.) this supports a need for further research with studies investigating caffeine's effect on non-trained participants.

2.5 Caffeine Habituation

Caffeine's ergogenic effect on performance can vary between athletes due to their habitual consumption of caffeine (Sokmen *et al*., 2008.). Athletes who have a lower habituation to caffeine are more sensitive to its ergogenic effects, compared to athletes who have a high habituation to caffeine (Bell and McLellan., 2002.). Regular caffeine consumption can cause changes in the metabolic responses to caffeine ingestion and can dampen the potential ergogenic effects of caffeine during exercise (Van Soeren and Graham., 1998.). Alternatively, it could be possible that any improvements from caffeine consumption in previous studies may be a result of a rebound from withdrawal when an acute caffeine dose is consumed, instead of a direct ergogenic effect of the caffeine dose (Irwin *et al*., 2011.). Bell and McLellan. (2002) investigated the difference in caffeine users and non-users time to exhaustion in a sub-maximal test when ingesting 5 $mg \cdot kg^{-1}$ BM dose of caffeine or placebo 1, 3 and 6 hours before testing. Their results found caffeine to have an ergogenic effect and increase performance for both groups compared to the placebo, but the ergogenic effect on performance in the non-users was found to be greater and longer lasting. However other studies by Van Soeren and Graham. (1998), Tarnopolsky and Cupido. (2000) and Astorino *et al.* (2011) go against the idea that habituation of caffeine affects caffeine's ergogenic effect on performance, showing no significant difference in users and non-users exercise performance. This highlights an area within the research of caffeine's effect on performance that could be explored further in future studies.

2.6 Mechanisms of Action

Research accepts that caffeine can have a positive effect as an ergogenic aid on performance, but the exact mechanisms in which it acts is un-clear (Davis and Green., 2009.).

2.6.1 Free-Fatty Acid Oxidation and Glycogen Sparing

Early mechanisms of caffeine's ergogenic effect on performance come from enhanced free-fatty acid oxidation and glycogen sparing (Davis and Green., 2009.). This mechanism first thought that caffeine stimulated an increase in adrenaline (epinephrine) output, which results in increased fat oxidation and mobilisation of fatty acids. This increase in metabolism of fat would therefore spare glycogen stores which will increase exercise endurance. This theory has been supported by Yeo *et al.* (2005) and Graham *et al.* (2008) however earlier studies from Graham *et al.* (2000) and Greer *et al.* (2000) don't support the theory as they found caffeine's effect to have no increase in fat mobilization or glycogen sparing.

2.6.2 Catecholamines

Studies have found catecholamine response to high-intensity exercise to show increased adrenaline secretion with caffeine consumption compared to placebo (Bell *et al*., 2001; Stuart *et al*., 2005; Davis and Green., 2009.). The increased adrenaline levels can potentially enhance performance by an increased glycolytic flux, however studies which have shown increased adrenaline levels and improved performance have not always shown increased glycolytic flux (Bell *et al*., 2001; Davis and Green., 2009.). Although caffeine has been found to increase adrenaline levels and enhance performance, it seems unlikely that it is the main mechanism responsible for the ergogenic effects of caffeine (Davis and Green., 2009.).

2.6.3 Adenosine Antagonism

Caffeine is known to stimulate the central nervous system (CNS), with the effect mediated through adenosine receptor antagonism (Davis and Green., 2009; Goldstein *et al*., 2010.). Adenosine is a compound made up of adenine and ribose, it has been found to be a powerful vasodilator. Adenosine metabolism occurs through adenine nucleotide breakdown. Exercise increases the adenosine concentrations within the skeletal muscle, smooth muscle, the circulatory system and the brain (Davis and Green., 2009.). Adenosine releases from neurons and has been shown to enhance pain perception, induce sleep, reduce arousal, depress spontaneous loco-motor activity and acts as a neuromodulator (Graham., 2001; Davis and Green., 2009; Goldstein *et al*., 2010.). Caffeine mechanisms inhibit effects on adenosine, which leads to modified pain perception whilst sustaining motor unit firing rates and neuro-excitability (Davis and Green., 2009). Pain reduces the output of muscles so by modifying pain perception can mean the muscles can continue to produce force and perform. This is why caffeine is commonly used in over the counter pain killers as it blockades adenosine receptors. This mechanism is the leading theory for the ergogenic effect of caffeine performance, especially during anaerobic performance (Graham., 2001; Davis and Green., 2009; Goldstein *et al*., 2010.).

2.7 Jump Squat Ergometry

The jump squat is an exercise that involves explosive triple extension of the ankle, knee and hip, it can be considered similar in explosive actions to that of sprinting and jumping in many sports (Kawamori and Haff., 2004; Turner *et al.*, 2012.). The jump squat does not accurately reflect any mainstream sport but is an effective training exercise to build lower body strength and develop explosive power (Argus *et al*., 2011.). Training at the optimal load has been found to be most effective at improving maximal power production and dynamic athletic performance in tests involving actions such as jumping, sprinting and agility, than other loading conditions (Hakkinen *et al.,* 1985; Wilson *et al.,* 1993; McBride *et al.,* 2002.). The optimal load for the peak power output in the jump squat exercise is well researched with the bulk of previous research finding the optimal load to be 0% of 1RM back squat or body weight (Stone *et al.,* 2003; Cormie *et al*., 2007; Cormie *et al*., 2008; Bevan *et al*., 2010; Dayne *et al*., 2011; McBride *et al*., 2011; Turner *et al*., 2012.). The recent study by Bevan *et al.* (2010) investigated the optimal loading for the development of peak power output in professional rugby players, 47 professional male rugby players participated, completing Jump Squats at loads of 0, 20, 30, 40, 50, and 60% of their predetermined 1RM, and peak power output was found to be at 0% load. This study used a large group of participants all of whom are resistance trained and well conditioned athletes, the results of this study agree with earlier studies and also more recent studies investigating optimal load for peak power in the jump squat

(Cormie *et al*., 2007; Cormie *et al*., 2008; Bevan *et al*., 2010; Dayne *et al*., 2011; McBride *et al*., 2011; Turner *et al*., 2012.) Performing lifts with a load that maximizes peak power output permits individuals to train at velocities similar to those encountered in actual on-field movement (Cormie *et al.,* 2007.). Early research from Hakkinen *et al.* (1985) reported that explosive body-weight jump training resulted in a 21% increase in jump height after 6 months of training, compared to heavy resistance training that resulted in a reduced improvement in jump height of 7%. This highlights the benefits of training using light loads that elicit high movement velocity and rate of force development to improve power output (Hakkinen *et al.,* 1985; Harris *et al.,* 2000; Jones *et al*., 2001.) However Kaneko *et al.,* (1983) earlier reported that strength training using heavy intensities resulted in improvements in maximal force output. Through improving max force output, the force generated at any given velocity is increased after training, leading to enhanced power output through the loading spectrum (Kaneko *et al.,* 1983.). Comparison of these two studies highlights the direct impact of increased strengths levels on power production (Hakkinen *et al.,* 1985; Wilson *et al.,* 1993; McBride *et al.,* 2002.).

CHAPTER 3

METHODOLOGY

3.0 Method

3.1 Subjects

Ten healthy, physically active and resistance trained male university students volunteered to participate in this study. The participants mean age, body mass and height was (21.4 ± 1.2 years, 87.1 ± 9.8 kg and 179.3 ± 4.4cm). All of the participants came from a sporting background, which included sports such as; rugby, football and hockey. All participants had very limited consumption of caffeine products such as tea and coffee, in their everyday lives, so could not be considered as caffeine naïve or habitual caffeine users. This study was approved by the Cardiff Metropolitan University Ethics Committee and subjects were provided with a participant information sheet (see Appendix A) to outline the study and its procedures. The participants then completed a pre-testing health questionnaire (see Appendix B) and gave their written informed consent (see Appendix C) prior participating in the study. The participants were made aware they would consume either a caffeine or placebo beverage prior to each testing, but they were not aware of the order in which they consumed the beverage prior to the two separate testing sessions.

3.2 Experimental Protocol

Participants attended the gym on two separate occasions to be tested; participants were informed before each visit to avoid consuming any substances containing caffeine for 12 hours prior to the testing sessions. The participants' diet was not controlled over the course of this study, but the participants were asked to maintain a similar diet for the 24 hr period before each testing session. Both testing sessions were conducted at the same time of day with a week in between testing sessions. All tests were performed using a non-loaded Olympic barbell (Eleiko 20kg Olympic Barbell, Halmstad, Sweden.) and the power output was measured by a Tendo accelerometer (Tendo Sports Machines, Trencin, Slovakia.) attached to the barbell.

3.2.1 Testing Procedure

Participants body mass was recorded using digital scales (SECA, Model 770, Hamburg, Germany.). In a double blind cross over design participants ingested either caffeine or placebo supplement 30 mins prior to testing then consumed the other supplement a week later in the other testing session, participants were aware they would consume both supplements during the testing sessions but not aware of which order they will consume the supplements. 20 mins after supplement ingestion participants performed a 5 minute standardised RAMP style warm up preparing them for the testing. Following the warm up, the last 5 minutes before testing the participants began familiarisation of the jump squat exercise, receiving instruction on the correct jump squat technique. The participants were instructed to begin by holding the barbell on their shoulders and with a set up of feet hip width apart, toes pointing forwards in a back squat position. Performance of the jump squat involved lowering the bar to the point where the knees were in 90 degrees of flexion, then immediately jumping explosively upwards as fast as possible with their feet leaving the floor while making sure to hold the bar tightly to the shoulders to complete a jump. Each participant was allowed multiple practice repetitions with feedback from the investigator to ensure correct and safe technique prior to testing. After this 5minute familiarisation period participants were ready to begin the testing 30mins after supplement ingestion as planned. Participants performed seven un-loaded barbell Jump Squats of maximal exertion, at 5-min intervals; 0, 5, 10, 15, 20, 25 and 30 mins. Anaerobic Power output of each Jump Squat was measured in Watts (W) by the Tendo Accelerometer with the values then recorded into a results table.

3.2.2 Caffeine Trial

During this trial each participant orally ingested a caffeine supplement containing 3 mg of caffeine per kg of body mass (BM) 30 mins prior to the testing. Caffeine was administered in the form of commercially-available caffeinated forest fruits TorQ sports gel, which also contained glucose (25g per 45g of caffeine gel). In line with the Cardiff Metropolitan University guidelines for ingested substances the supplement was measured and made in the physiology departments' lab prior to testing. Each supplement was specifically measured using laboratory scales (Kern EMB Precision Balance Laboratory Scales) to ensure each participant received the correct dosage level in relation to their mass recorded earlier at the beginning of the study. Water was added to the caffeine gels until the total volume of the drink was equal to 500ml; this was then mixed together within the shaker cup and administered to the participant 30mins prior to testing.

3.2.3 Placebo Trial

During this trial each participant orally ingested a placebo supplement containing glucose (35g per 45g of non-caffeinated gel) 30-mins prior to testing. Placebo was administered in the form of a commercially available non-caffeinated cherry yoghurt TorQ sports gel of similar flavour to the caffeinated forest fruits TorQ sports gel. The consistency of the placebo was the same as that of the caffeine supplement by using the same amount of gel. Water was again added to the sport gels until the total volume of the drink was equal to 500ml; this was then mixed together within the shaker cup and administered to the participant 30mins prior to testing.

3.3 Statistical Analysis

The data collected during both testing sessions was recorded into a spreadsheet on Microsoft Excel. The statistical analysis of the data in this study was done using SPSS 20 statistical package (IBM Solutions, USA.), with the significance level set at $P<0.05$ for the statistical analysis. Participants' descriptive data (age, weight and height) was displayed as mean (±SD). All raw data collected was recorded into a table using Microsoft Excel (Microsoft, USA) and can be found in Appendix (D). Differences in the PPO values of the caffeine and placebo trials were compared using a one-way analysis of variance (ANOVA) with repeated measures. Also the results are shown as mean ± SD for MPO and TPO done for both caffeine and placebo trials, using a paired sample T-Test to analyse both. All graphical representations of data were produced using Microsoft Excel (Microsoft, USA).

CHAPTER 4

RESULTS

4.0 Results

Of the original 10 participants who volunteered, 8 completed the study. No participants reported any side effects from the study either after ingesting the caffeine beverage or placebo beverage. The PPO values (Watts) of each participant during the placebo and caffeine trials are displayed in Table (1) below. Although some increases in PPO can be seen for six participants between the placebo and caffeine trials, these differences however were not significant (*P*>0.05).

Table (1). JS – PPO values (Watts) of participants during the placebo and caffeine trials (n = 8).

Participant	1	2	3	4	5	6	7	8
Placebo	2219	2224	1722	3068	2128	2225	2137	2329
Caffeine	2360	2224	1832	2854	2227	2466	2154	2573

Figure (1) below further displays the PPO values (Watts) of the participants during the placebo and caffeine trials for the jump squat, with six participants displaying an increase in PPO after caffeine ingestion compared to placebo.

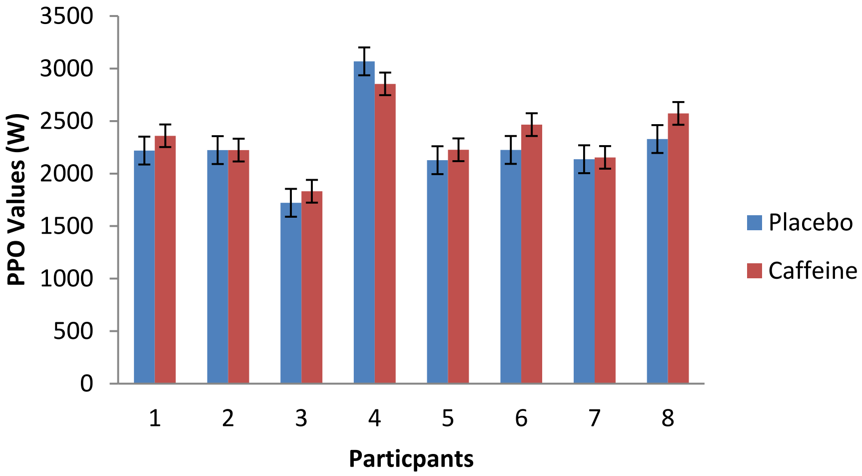

Figure (1). Comparison of each participant's JS – PPO values (W) after placebo and caffeine supplementation.

The participants' total PO (Watts) completed over the 7 jump squats during the placebo and caffeine trials are displayed in Table (2) below. For seven of the eight participants increases in total JS – PO (Watts) from all seven jumps can be seen between placebo and caffeine trials, with the differences significantly different (*P*<0.05).

Table (2). Total JS – PO values (Watts) of participants during the placebo and caffeine trials (n = 8).

Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Placebo	15047	14793	11512	19181	14644	15101	14095	15891
	*	*	*	*		*	*	*
Caffeine	15571	15210	12156	19549	14471	15445	14565	17297

***** denotes significant difference (*P*<0.05) in total power output exerted over the 7 jump squats in the caffeine trial compared to placebo.

Figure (2) below further displays each participants' total PO values (Watts) completed over 7 jump squats during the placebo and caffeine trials, with seven participants displaying an increase in total PO after caffeine ingestion compared to placebo.

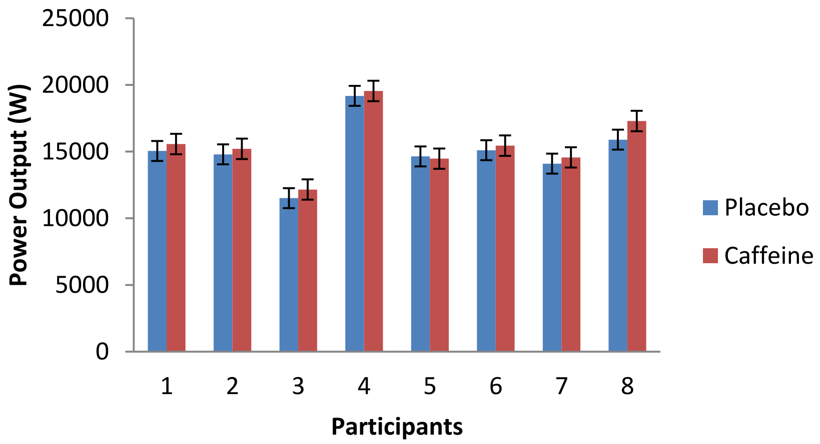

Figure (2). Comparison of each participants total JS – PO values (W) after placebo and caffeine supplementation.

The mean (±SD) value of total PO (Watts) of all participants in the placebo and caffeine trials is depicted in Figure (3) below, significantly more power was exerted overall during the caffeine trial compared to the placebo trial (*P*<0.05).

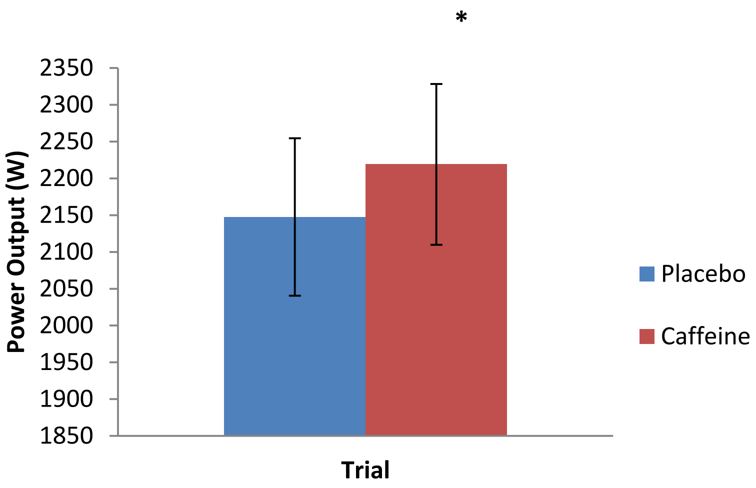

Figure (3). Mean (±SD) values of total PO (W) within the placebo and caffeine trials.

***** denotes a significant difference (*P*<0.05) between caffeine and placebo trials for total power output (Watts).

The mean (±SD) of total work completed by participants in each set of jump squats in the placebo and caffeine trials is depicted in Figure (4) below. During each set the figure shows that more total power was exerted during all sets of the caffeine trials compared to the placebo trials, with the differences significantly different (*P*<0.05).

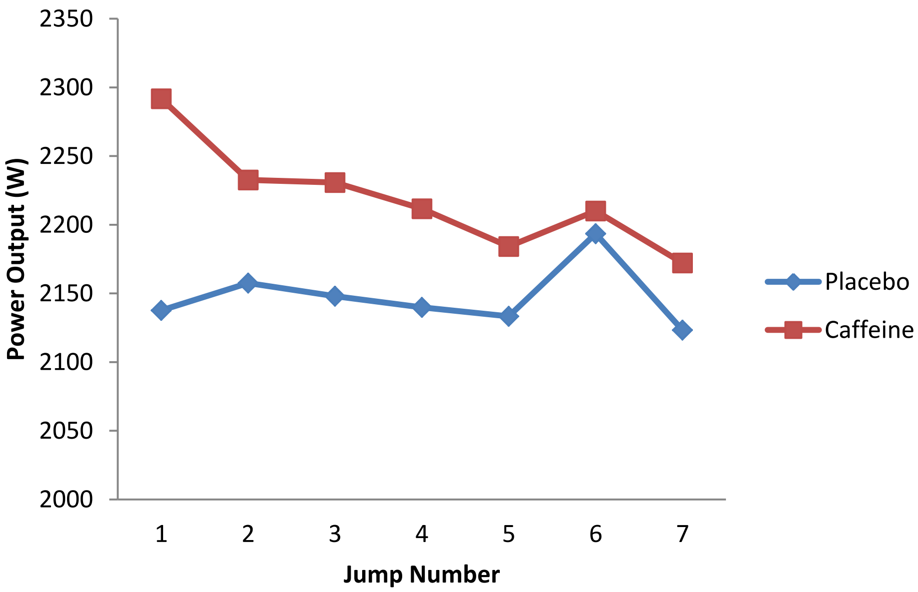

Figure (4). Mean values of PO (W) within each set of the placebo and caffeine trials.

CHAPTER 5

DISCUSSION

5.0 Discussion

5.1 Overview of the Present Study

The purpose of the present study was to investigate the effects of acute caffeine consumption on jump squat PPO within trained male sports university students. A caffeine dose of 3 $mg\text{-}kg^{-1}$ BM was administered 30 minutes prior to exercise testing. The jump squat was the chosen exercise to be used within the study; participants completed 7 sets of 1 maximal unloaded jump squats with a 5 minute rest in between jumps. Other studies have looked at the effect of caffeine on the upper body using the bench press and the lower body using the Wingate test or repeated sprints (Beck *et al.,* 2006; Bell and McLellan., 2006; Crowe *et al.,* 2006; Forbes *et al.,* 2007; Woolf e*t al.,* 2008; Woolf *et al.,* 2009.).

The major findings of the present study are that caffeine increased lower body muscular performance with the MPO and TPO significantly increased during the caffeine trial, compared to placebo. Seven of the eight participant's TPO over the 7 sets of jump squats was increased with caffeine ingestion. Furthermore, each of the 7 sets of jump squats showed an increase in MPO after caffeine ingestion compared to placebo ingestion. In relation to the hypothesis of the current study, the results reported provide evidence that over 7 sets of unloaded jump squats caffeine can improve power output. However, there was no significant difference in PPO values between caffeine and placebo trials for the jump squat and could be due to the small participant sample size. Although there was no significant increase in PPO values across the group, some improvements were visible with six out of the eight participants showing slight improvements in their PPO values following caffeine ingestion, but were not statistically significant.

5.2 Mechanisms in Relation to Anaerobic Power Output

The current results indicate that caffeine does not significantly increase lower body PPO values of participants in the jump squat exercise, with the results only indicating that caffeine significantly increases lower body MPO and TPO of participants. This finding is similar to that of a study by Forbes *et al.* (2007) who also investigated lower body PPO and MPO values after caffeine ingestion, reporting that caffeine had no significant effect on lower body PPO or MPO. However, this study used a lower

2mg·kg^{-1} BM dose of caffeine and a different exercise, using the Wingate test as a measure of lower body PPO and MPO, so direct comparisons between this and the present study must be taken with caution. Conversely, Woolf *et al.* (2008) reported that a caffeine dose of 5mg·kg^{-1} significantly increased PPO in the Wingate test compared to the placebo. The differences in findings may be due to the caffeine dosage levels, type of caffeine supplement consumed, training status of participants, and exercise protocols used within the studies. However within the literature the mechanisms by which caffeine elicits ergogenic effects is not clearly understood and need to be investigated further (Crowe *et al.,* 2006.).

5.3 Caffeine Dose Administered

During the present study a caffeine dose of 3 mg·kg^{-1} BM was administered to the participants via a beverage formed by water being added to a measured amount of TorQ sports caffeinated gel specific to each participants BM, with the same amount of TorQ sports non-caffeinated gel being mixed with water for the placebo beverage. This caffeine dosage did not elicit any significant effects on PPO during the jump squat testing, but did elicit significant improvements in MPO and TPO, compared to placebo. Dosage levels for ergogenic benefits have been varied within the literature with caffeine dosage levels ranging from 1 to 15 mg·kg^{-1} BM (Bell and McLellan., 2002.).

A previous study by Beck *et al.* (2006) used a similar caffeine dosage to that of the present study; around 3 mg·kg^{-1} BM. The study investigated caffeine's effect on strength, muscular endurance and anaerobic capabilities, in particularly lower body anaerobic performance in the Wingate test; a common test used to measure PO in the lower body. The results found that the 3 mg·kg^{-1} BM dose of caffeine ingested 60 mins before testing had no significant effect on PPO and MPO of resistance trained males. This result is similar to that of the present study as no effect on lower body PPO was found in resistance trained males, however the present study found improvements in mean power output, this questions the timing of caffeine ingestion prior to exercise and exercise choice as possible factors why the results conflict.

Conversely a previous study by Woolf *et al.* (2008) used a higher dose of 5 mg·kg^{-1} BM to investigate caffeine's effect on Wingate performance in resistance trained male athletes, with results showing a greater PPO in the Wingate test after caffeine ingestion 60 minutes prior to testing. This result compared to that of the present study and that of Beck e*t al.* (2006) highlights that caffeine dosage level could be responsible for ergogenic effects on anaerobic performance. However, an earlier study by Crowe *et al.* (2006) employed a caffeine dosage of 6mg·kg^{-1} BM within their study, investigating its effect on repeated maximal cycling bouts similar to a Wingate test. With the results not supporting that of the study by Woolf e*t al.* (2008) with results indicating that the 6 mg·kg^{-1} BM dose of caffeine had no ergogenic effect on repeated maximal cycling bouts and could be detrimental to anaerobic performance. Some factors must be considered when comparing these two studies, the ingestion times were different, Crowe e*t al.* (2006) study participants ingested caffeine 90mins prior to testing, with Woolf e*t al.* (2008) study ingesting caffeine only 60mins prior to testing, this could possibly effect the ergogenic effects on participants. The studies exercises tests were different, with Woolf e*t al.* (2008) study using the more recognised Wingate testing protocol, than Crowe *et al.* (2006) less recognised repeated cycle sprints. Also the sample groups were different with Crowe *et al.* (2006) participants made up of non-specifically trained individuals and Woolf e*t al.* (2008) participants were made up of resistance trained individuals, this highlights training status may be a factor to consider. With the optimal dose of caffeine not determined, it has been suggested within the literature that it may vary according to factors such as sensitivity of the individual to caffeine and training status (Bell and McLellan., 2002.).

5.4 Training Status of Participants

The participant group used within the present study consisted of male sports university students who are well-trained team sport athletes who either compete at university or amateur club level. As suggested in the current study the training status of the participants may enhance the effectiveness of caffeine as an ergogenic aid for performance. Woolf *et al.* (2009) suggests that caffeine may affect trained and non-trained participants differently; with trained participants potentially benefitting more from the ergogenic effect of caffeine. A possible reason for this is that athletes from elite backgrounds who train more regularly will generally have more muscle mass than athletes from recreational levels who don’t train as regularly. It has been speculated that caffeine acts directly on the muscle fibres, so therefore caffeine will have greater effect on athletes with a larger muscle mass (Woolf *et al.,* 2009.).

Furthermore, another possible reason could be that elite/trained athletes are more competitive and may have greater motivation to perform and train at higher more exhaustive levels than that of less trained/recreational athletes (Burke., 2008.).

The results from the present study support the previous theories within the literature that trained athletes respond better to caffeine and benefit more from its ergogenic effects, than non-trained individuals. The participants used within the present study however were not elite, but were of a respectable level (university/amateur) within their respective sports, with all participants well-trained and fully accustomed to resistance exercise. The results from the present study report that caffeine ingestion can increase total work completed and mean power output values in the jump squat but not increase peak power output values. The first published study to specifically investigate caffeine's ergogenic effects on trained and un-trained individuals was by Collomp *et al.* (1992) who investigated caffeine's effect on a swimming sprint test measuring anaerobic performance in trained and non-trained swimmers. The results found that a caffeine dosage of 250 mg improved the velocity of the trained swimmers more than non-trained, giving early indications that trained individuals may gain greater performance enhancing benefits from caffeine ingestion than un-trained individuals. With the lack of research on the area, it highlights a need for future studies to use trained and untrained individuals and further investigate caffeine's effect on both.

5.5 Timing of Caffeine Ingestion

The timing of caffeine ingestion prior to exercise could be a possible reason as to why the previous research on caffeine's ergogenic effects on anaerobic performance is mixed. Graham. (2001) and Goldstein *et al.* (2010) have documented that caffeine is completely absorbed within the stomach and small intestine 30 – 60 mins after ingestion with a half-life of approximately 3 - 10 hours within the body. The timing of caffeine and placebo ingestion in the present study was acute with participants ingesting the caffeine or placebo beverage 30 mins before each exercise testing session. The testing itself lasted 30 mins, with the participants completing each testing session 60 mins after supplement ingestion. This acute supplementation could be a possible reason why the results found no significant increase in PPO of participants, however an increase in MPO and TPO was found in participants. This mixed finding questions the timing of caffeine ingestion, with the present study finding an enhancement in performance after as little of 30 mins.

An earlier study by Hoffman *et al.* (2007) used physically active college students like that of the present study, to investigate nutritionally enriched coffee on aerobic and anaerobic exercise performance. The study used the Wingate test as a measure of lower body anaerobic performance with the results reporting that ingestion of coffee and placebo ingestion 30 mins prior to test had no significant effect on anaerobic PPO and MPO values. This result is similar to that of the present study and indicates that caffeine may take longer than 30 mins to elicit ergogenic effects on anaerobic performance. More recent studies by Beck *et al.* (2006); Forbes *et al.* (2007) and Woolf *et al.* (2008) all measured lower body anaerobic performance using the Wingate test with physically active participants ingesting caffeine 60 mins prior to exercise testing. The study by Woolf *et al.* (2008) was the only one to find caffeine to have an effect on the Wingate test, finding caffeine increased PPO, all the other studies found caffeine to have no effect on anaerobic performance when compared to placebo. The study by Woolf *et al.* (2008) used a caffeine dosage of 5 $mg \cdot kg^{-1}$ BM higher than that of the previous studies by Beck *et al.* (2006); Forbes *et al.* (2007) and the present study. With this study being the only one to report an increase in anaerobic performance during the Wingate test, could mean that dosage levels of caffeine could be an important factor when using caffeine as an ergogenic aid.

Alternatively, a study by Crowe *et al.* (2006) investigated the effects of a 6 $mg \cdot kg^{-1}$ BM dosage of caffeine's on repeated maximal cycle sprints 90 minutes after ingestion, with results finding that caffeine had no significant effect on peak power or average work output of participants compared to placebo. Moreover, an earlier study by Bell and McLellan. (2002) investigated exercise endurance 1, 3, and 6 hours after caffeine ingestion in caffeine users and non-user. The study measured time to exhaustion in a maximal cycling endurance test with participants ingesting a 5$mg \cdot kg^{-1}$ BM dose of caffeine or a placebo, 1, 3, or 6 hours before each testing session. The study reported caffeine to significantly increased time to exhaustion times in non-users 1, 3 and 6 hours after ingestion compared to placebo and in caffeine users only 1 and 3 hours seen significant improvements. Although the study measured caffeine's effect on aerobic exercise it still highlighted that caffeine can elicit ergogenic effects on performance up to 6 hours after ingestion, thus agreeing with

Graham. (2001) and Goldstein *et al.* (2010) mentioned earlier, who documented that caffeine has a half-life of approximately 3 - 10 hours within the body. This highlights that the timing of caffeine ingestion and anaerobic exercise could be areas for future research. Moreover, during Bell and McLellan. (2002) the non-users of caffeine showed greater improvements in performance than caffeine users, this raises caffeine habituation as a factor that may effect the potential ergogenic effects caffeine can elicit on exercise performance.

5.6 Caffeine Habituation of Participants

Within the present study the pre-testing questionnaire found that the participants are not habitual caffeine users, consuming the equivalent of less than a cup of coffee each a day. As it has been documented that habitual caffeine consumption may result in the development of tolerance to the acute effects of caffeine (Robertson *et al.,* 1981), this regular caffeine consumption may dampen the ergogenic potential of caffeine during exercise (Van Soeren and Graham., 1998.) so suggests that the participants within the present study will have low tolerance levels and benefit from potential ergogenic effects of caffeine on performance. However this was not entirely the case, with the participants showing no significant increase in PPO values compared to placebo in the testing, with only an increase in MPO and TPO being observed. However the results of the present study do not support that of an earlier investigation by Woolf *et al.* (2008) which found that caffeine increased PPO in the Wingate test of participants who are non-habitual caffeine users. In comparison, the results of both of these studies are mixed and different, but do suggest that caffeine can elicit some ergogenic effects for non-habitual/low caffeine users during anaerobic exercise. However, the findings of previous studies by Beck *et al.* (2006); Forbes *et al.* (2007) and Woolf *et al.* (2009) suggest otherwise, with all studies finding no increases in performance after caffeine ingestion for non-habitual/low caffeine users. Within the literature there is a lack of research investigating the ergogenic effects of caffeine on anaerobic performance in caffeine users and non-caffeine users. A study by Bell and McLellan. (2002) has investigated the effects of caffeine on exercise endurance in caffeine users and non-users, with the results indicating that caffeine significantly improved time to exhaustion in both users and non-users, with the effects being greater and lasting longer in the non-users. This lack in research highlights a need to further investigate caffeine’s ergogenic effects on exercise performance in habitual and non habitual caffeine users as the caffeine habituation of an individual could be a factor in whether or not caffeine will improve exercise performance.

5.7 Limitations of the Present Study

In the present study various factors may have effected or influenced the results of the study. The main limitation of the present study was the small number of subjects employed to participate (N=8). A larger sample size would provide a more valid analysis of caffeine's effect on anaerobic PPO and MPO, with inter-participant variation having less impact on the results.

Another limitation of the study in relation to the exercise protocols relates to the type of exercise performed, participants familiarity and experience of jump squatting could vary, thus effecting the performance within testing. Participants more experienced in using the exercise will be more comfortable performing the exercise than participants who are less experienced. Although participants underwent familiarisation of the technique required for the testing it may not have been long enough for all participants to be completely comfortable to efficiently perform the exercise, so in future studies a separate familiarisation sessions should take place.

Furthermore, within the present study all participants ingested the placebo supplement prior to the first testing session and ingested the caffeine supplement prior to the second testing session. Therefore, during the second testing session participants were already familiar with the testing procedure, exercise protocols and techniques, as they would have done the same the week before in the first testing session. This familiarisation could be an explanation for some of the performance increases found between the trials. Future studies should employ a randomised approach to beverage consumption to eliminate this limitation.

Some factors that could effect the results were outside of the researchers control, factors such as; participants dietary intake, exercise, sleep and caffeine intake prior to each testing session. Structure was applied to the testing conditions with both testing sessions taking place at the same time on a Tuesday morning with a week's rest in between the sessions. The participants were instructed not to consume caffeine for up to 12hours prior to testing and to keep their dietary intake the same or relatively similar prior to both testing sessions. This put trust into the participants to follow the simple pre-testing instructions to ensure a fair trial.

If caffeine was consumed in the 12hours before the placebo trial then this could have effected the trial and made the results invalid as there would have been traces of caffeine in the participants system when there wasn't supposed to. Also if caffeine was ingested in the 12hours prior to the caffeine trial then there will be more caffeine in the participants system than the dosage level the study was looking to investigate, again effecting the results and giving a false representation of the trials aims. Also the consistency of the dietary intake of participants prior to each testing session could have effected performance, if the participants consumed food before the first testing session and not before the second testing session this will effect the participants performance. The lack of consistency in dietary intake could either positively or negatively effect energy levels during testing sessions so was important that participants kept dietary intake prior both sessions the same so each participant should have the same or similar preparation and energy levels in both sessions. Furthermore the participants could have trained prior to the testing session on the morning or night before which could have fatigued the individual and negatively effecting the performance within the testing. Lastly, the participants sleeping pattern could be inconsistent between tests which could have caused the participant to be tired prior and during the testing which could effect their performance and adaptations to supplements.

5.8 Practical Implications

The implications for athletes seeking a legal ergogenic aid to improve anaerobic performance can take from this study that a moderate 3 $mg \cdot kg^{-1}$ BM dose of caffeine ingested 30 minutes prior to anaerobic exercise does not significantly increase PPO within the jump squat exercise, but does however significantly improve MPO and TPO. With caffeine being a readily available, safe and legal drug it could be recommended as an ergogenic aid for athletes who participate in anaerobic exercise and are looking to improve average power output and total work done in training or competition.

5.9 Future Research

Within the literature the effects of caffeine ingestion on anaerobic exercise and performance is mixed and is less understood than the effects of caffeine on aerobic exercise and endurance (Beck *et al.,* 2006). The results reported from the present study could contribute to the knowledge and understanding of the ergogenic effects of caffeine on anaerobic performance. However, there is still a need for further research to take place to expand the current research and further knowledge within the topic area. Future research should aim to investigate caffeine effects on anaerobic performance using different exercises to that of the present and previous studies, preferably looking at more specific exercises and actions that take place within sports. Furthermore, future research should investigate the precise mechanisms which caffeine acts on to enhance anaerobic performance, as the precise mechanisms still remain unknown, with only potential mechanisms being suggested in previous literature. Lastly further research should investigate the possible factors that could effect the ergogenic effects on anaerobic performance, factors such as; caffeine dosage levels, participants training status and timing of caffeine ingestion.

CHAPTER 6

CONCLUSION

6.0 Conclusion

The findings of the present study partly support the hypothesis made. The main finding of the present study is that a 3 $mg \cdot kg^{-1}$ BM dose of caffeine ingested 30 mins prior to anaerobic exercise significantly increased mean power output in each set and total work completed by participants in the jump squat exercise over seven sets, which supports the hypothesis that mean power output and total work completed will increase after caffeine ingestion and that caffeine can elicit some ergogenic effects on anaerobic exercise. However, caffeine was found to not significantly increase peak power output values of the participants in the jump squat exercise, which did not support the hypothesis and supports pasts research that caffeine does not affect anaerobic performance (Beck *et al.,* 2006; Crowe *et al.,* 2006; Forbes *et al.,* 2007; Glaister *et al.,* 2012.).

As previously suggested a limitation of the present study is the size of the participant group which may have affected the statistical significance of some areas within the study. If a larger participant group was used, the study may have more statistical significance with variation between participant's results having less effect on the statistical analysis.

The current study provides key applications to knowledge in relation to caffeine dosage level and timing of ingestion. Suggestions regarding the optimum caffeine dose for increasing anaerobic performance is varied and in some cases conflicting. Commercial caffeine products commonly consumed have differing dosage levels of caffeine, this study reports that a moderate dose of 3 $mg \cdot kg^{-1}$ BM can elicit ergogenic effects on anaerobic performance, improving MPO and TPO. Furthermore, no side effects were observed in the present study with participants reacting well to the moderate dosage of caffeine compared to negative side effects observed in an earlier study by Woolf *et al.* 2008 who reported participants feeling negative side effects such as physical shakes and increased heart rate after a larger dose of caffeine than that used in the present study which was likely to have affected the participants performance. The present study also confirms that caffeine consumption 30 mins prior to exercise is long enough for caffeine to effect performance and elicit ergogenic effects, adding to the existing knowledge of caffeine and anaerobic performance.

The final conclusion of the present study is that a 3 $mg \cdot kg^{-1}$ BM dose of caffeine ingested 30 mins prior to exercise can elicit some anaerobic performance improvements, with caffeine enhancing MPO and TPO. However, caffeine's effect on PPO still remains unknown and unclear, so future research needs to take place considering suggestions made previously in the current study, to further research the effects of caffeine on anaerobic performance, in particularly PPO.

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APPENDICES

APPENDIX A

Participation Information Sheet

Project Title: The effects of acute caffeine consumption on jump squat power output.

This document provides a run through of:

1) the background and aim of the research,
2) my role as the researcher,
3) your role as a participant,
4) benefits of taking part,
5) how data will be collected, and
6) how the data / research will be used.

The purpose of this document is to assist you in making an *informed* decision about whether you wish to be included in the project, and to promote transparency in the research process.

1) Background and aims of the research

Pre-workout Energy drinks are rapidly growing in popularity and becoming common place in athletes and fitness enthusiasts training routines and also competition. The common ingredient in all pre-workout drinks is caffeine and it is this substance which is thought to have an ergogenic effect on athletic/physical performance. There is plenty of research looking into caffeine ergogenic effect on aerobic endurance and time to exhaustion, however there is very limited research on anaerobic exercise. So based on the overview I am looking to see the effect acute caffeine supplementation on jump squat power output.

2) My role as the researcher:

The study involves me (James Boulton), the researcher, and I will be conducting 2 controlled jump squat testing sessions with a week's gap in between, where at the beginning of the testing sessions you the participant will have consumed a caffeine supplement with the caffeine dosage level of 3mg per kg of body mass or placebo supplement, then perform seven jump squats with five minute intervals in between. The test will be double blind so neither you the participant or I the researcher will know what drink you have taken.

3) Your role as a participant:

Your role is to commit to two jump squat testing sessions where you will take a caffeine supplement or placebo prior to both sessions. The participants will be split into two equal groups, where either a caffeine supplement or placebo will be taken for that testing session, and then a week later return and your group will take the opposite supplement. Prior to both testing sessions you the participant need to refrain from any caffeine consumption (e.g. coffee, redbull, tea, coke etc) for 12 hours prior to testing, as it could have effect on the ergogenic effects of the studies supplements on performance. In these testing sessions you will be required to perform seven maximal unloaded barbell jump squats where I will record the results and then analyse.

4) Benefits of taking part:

The information we obtain from this study will allow better insight into the effects of caffeine on anaerobic performance. From this we will aim to understand why and how caffeine effects performance. I will be happy to share this information to any of the participants of this study. On request, we can also provide you with your own personal jump squat results, how you responded to both supplements, and discuss this with you in relation to your own sporting performance.

5) How data will be collected:

As alluded to above, data will be collected solely from the testing sessions when the jump squats are being performed.

6) How the data / research will be used:

In agreeing to become a _voluntary_ participant, you will be allowing me to use your results from the testing sessions and include them within a larger data set that includes the data of other participants. Your personal data will be anonymous and will not be reported alone, but within the total sample of participants.

Your rights

Your right as a _voluntary_ participant is that you are free to enter or withdraw from the study at any time. This simply means that you are in full control of the part you play in informing the research, and what _anonymous_ information is used in its final reporting.

Protection to privacy

Concerted efforts will be made to hide your identity in any written transcripts, notes, and associated documentation that inform the research and its findings. Furthermore, any personal information about you will remain _confidential_ according to the guidelines of the Data Protection Act (1998).

Contact

If you require any further details, or have any outstanding queries, feel free to contact me on the details printed below.

James Boulton
Cardiff School of Sport
Cardiff Metropolitan University
CF236XD, United Kingdom
St10001849@cardiffmet.ac.uk

APPENDIX B

PARQ - The effects of acute caffeine consumption on jump squat power output:

Pre-Testing Screening Questionnaire

This is a short questionnaire to screen your suitability for participation within this study.

Name:

Student Number: **Email:**

D.o.B:

Weight (kg): **Height (cm):**

Mobile Number:

Sport:

……..

What is your current health? E.g. are you fit & healthy or suffering from any illnesses, injuries etc.

What is your current level of physical fitness and training status? E.g. are you in training and participating in your sport or not currently participating in your sport or training. How many times a week do you train etc.

What is your previous injury history? Please state the type and date of injury or injuries.

Are you currently taking any medication? If so, what medication and the reasons behind it.

Do you have any allergies? In particular any allergies to caffeine? If so name the allergies.

Do you consume caffeine? If so, in what form? E.g. Redbull, coffee etc.

Are you sensitive to caffeine? Does it have any negative effects on you? Such as headaches, nausea, sickness etc.

On a weekly basis how much caffeine do you consume? E.g. 4 cups of coffee, 2 cans of Redbull and 5 bottles of coca-cola.

Following this questionnaire is there any reason in which you shouldn't take part in this study or any questions you have about the study?

Are you happy and ok to participate in the study?

Signature: **Date:**

APPENDIX C

CARDIFF METROPOLITAN UNIVERSITY

INFORMED CONSENT FORM

CSS Reference No:

Title of Project: The effect of acute caffeine consumption on jump squat power output.

Name of Researcher: James Boulton

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the participant information sheet for this study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that it is possible to stop taking part at any time, without giving a reason. ☐

3. I also understand that if this happens, our relationships with the Cardiff Metropolitan University or our legal rights will not be affected. ☐

4. I understand that information from the study may be used for reporting purposes, but I will not be identified. ☐

5. I agree to take part in this study on 05/02/13 & 12/02/13. ☐

…………………………………………………………………………………

Name of Participant

Signature of Participant Date

……………………………………………………………………………………

Name of person taking consent

Signature of person taking consent Date

* When completed, one copy for participant and one copy for researcher's files.

APPENDIX D

Raw Data

Participant Descriptive Data				
Particiapnt	**Age**	**Weight (kg)**	**Height (cm)**	**Caffeine Dosage**
1	21	80	176	240
2	23	85	178	255
3	22	70	178	210
4	23	104	188	312
5	20	92	176	276
6	20	88	183	264
7	21	89	175	267
8	21	89	180	267

Jump Squat Testing Data						
	Placebo			**Caffeine**		
Participant	**Peak Power Output (Watts)**	**Average Power Output (Watts)**	**Total Work Completed (Watts)**	**Peak Power Output (Watts)**	**Average Power Output (Watts)**	**Total Work Completed (Watts)**
1	2219	2149.6	15047	2360	2224.4	15571
2	2224	2113.3	14793	2224	2172.9	15210
3	1722	1644.6	11512	1832	1736.6	12156
4	3068	2740.1	19181	2854	2792.7	19549
5	2128	2092	14644	2227	2067.3	14471
6	2225	2157.3	15101	2466	2206.4	15445
7	2137	2013.6	14095	2154	2080.7	14565
8	2329	2270.1	15891	2573	2471	17297

Placebo Individual Set Power Output Values (Watts)							
Participant	**Set 1**	**Set 2**	**Set 3**	**Set 4**	**Set 5**	**Set 6**	**Set 7**
1	2156	2219	2093	2133	2180	2133	2133
2	2074	2107	2041	2182	2107	2224	2058
3	1612	1633	1660	1571	1722	1681	1633
4	2670	2752	2772	2701	2517	3068	2701
5	2002	2119	2128	2128	2119	2020	2128
6	2165	2182	2225	2113	2182	2087	2147
7	2137	1919	2015	1962	2050	2050	1962
8	2285	2329	2250	2329	2189	2285	2224

Caffeine Individual Set Power Output Values (Watts)							
Participant	**Set 1**	**Set 2**	**Set 3**	**Set 4**	**Set 5**	**Set 6**	**Set 7**
1	2336	2180	2117	2133	2360	2289	2156
2	2207	2166	2224	2091	2166	2207	2149
3	1749	1832	1770	1770	1660	1694	1681
4	2854	2803	2752	2833	2752	2752	2803
5	2227	2119	2119	2083	1929	2020	1974
6	2329	2130	2285	2466	2070	2130	2035
7	2111	2058	2058	2032	2137	2015	2154
8	2521	2573	2521	2285	2399	2573	2425