Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

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Student name: Gabrielle Thomas	***Student ID:*** St20009851
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Comments	Section
	Title and Abstract (5%) Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review (25%) 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 (15%) To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.
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CARDIFF METROPOLITAN UNIVERSITY

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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT CONDITIONING, REHABILITATION AND MASSAGE

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Is coffee an effective pre-workout drink? – *The effects of ingesting naturalistic doses of caffeine on one-repetition maximum muscular strength and muscular endurance in females.*

Dissertation submitted under the discipline of SCRAM

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Is coffee an effective pre-workout drink?

– The effects of ingesting naturalistic doses of caffeine on one-repetition maximum muscular strength and muscular endurance in females.

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I would like to acknowledge Jason Pedley for his support, guidance and knowledge and I would also like to extend my thanks to the participants who volunteered to take part in the present study.

ABSTRACT

Extensive research has been conducted on the ergogenic effects of caffeine for endurance performance yet far fewer studies have investigated the effects for intense, short-term exercise. Particularly lacking in documented literature is the effects of acute caffeine ingestion in female athletes. This study aimed to investigate the ergogenic potential of caffeine on upper body and lower body muscular strength and endurance in females. Fourteen female participants (age 21.1 ± 0.7 years, body mass 65.9 ± 9.5 kg, stature 165.4 ± 7.4 cm) with one year's resistance training experience ingested caffeine (61 mg) or placebo 1 hour (hr) prior to testing, in a single-blind crossover design. The participants completed their 3 repetition maximum (3RM) before performing repetitions to failure set at 60% of their estimated 1RM, for barbell bench press and leg press. A series of paired t-tests were performed between the control, caffeine and placebo trials to determine a difference in performance, where 95% significance ($P \leq 0.05$) was applied. There was no effect (standard error of difference = 0) of caffeine on muscular strength, as 1RM bench press (42.39 ± 7.25 kg) and 1RM leg press (112.26 ± 38.73 kg) were the same for all three trials. Compared to placebo, there was a significant increase in repetitions to failure for bench press (20 ± 3 reps vs. 22 ± 3 reps, $P = 0.001$) and leg press (23 ± 8 reps vs. 25 ± 8 reps, $P = 0.000$). The mechanisms supporting the increased number of repetitions with caffeine need to be explored in more detail. Caffeine habituated participants were more responsive to the effects of caffeine than non-users during the caffeine and placebo trials (bench press: $P = 0.006$ vs. $P = 0.052$ and leg press: $P = 0.003$ vs. $P = 0.018$). However, a few factors were identified that may have affected these results. Consequently, future studies should investigate individual participant responsiveness to establish whether they are responders to caffeine or not.

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Ergogenic Aids

In an attempt to enhance performance, increase endurance, control body weight, or promote muscle development, athletes frequently take dietary supplements. Some may do this by simply manipulating the macro or micronutrients they consume beforehand, by ingesting select diet-derived compounds such as caffeine and creatine (Thomson, 2010) or by taking commercially available pre-workout stimulants and supplements. These commercially available supplements usually consist of a vast list of ingredients commonly including large quantities of caffeine.

1.2 Caffeine as an Ergogenic Aid

Caffeine is a substance that has a pharmacological effect on the body (Bean, 2001). It is classed as a drug rather than nutrient but is still considered a ‘nutritional supplement’ because it is found in many everyday drinks and sporting supplements. It is the world's most widely consumed psychoactive drug, but unlike many other psychoactive substances, it is legal and unregulated in nearly all parts of the world.

Caffeine is an adenosine antagonist with many physiological and psychological effects. It acts as a central nervous stimulant and can alter neuromuscular function and/or skeletal muscular contraction (Lopes et al. 1983). It can spare glycogen utilization by acting to increase fat oxidisation. Caffeine ingestion has also indicated enhanced secretion of β-endorphins during exercise with a subsequent decrease in perceived sensation of pain induced by exercise (Motl et al. 2003) as well as an enhanced thermogenic response and reduced perceptions of fatigue (Graham 2001).

1.3 Rationale to Support This Research Study

1.3.1 Caffeine's Ergogenic Effect on Muscular Strength and Endurance

There have been multiple studies conducted examining the effect of caffeine in aiding endurance performance and aerobic capacity. From which, it is evident that caffeine supplementation in moderate to highly trained endurance athletes provides an ergogenic response in performance. However, research in the effects of caffeine on muscular performance is diminutive, particularly the acute effects of caffeine ingestion on dynamic muscular strength and muscular endurance. It is an important area to investigate as there are a large number of athletes using it with the belief of enhancing performance. Therefore with the lack of current literature, there are many research prospects surrounding this topic, making the effects of caffeine on muscular strength and endurance performance a viable investigation to pursue.

1.3.2 Caffeine's Ergogenic Effect on Female Athletes

Previous studies looking at the effects of caffeine supplementation in endurance, high-intensity, or strength training in females is scant, especially when compared to the available literature that have investigated these dynamics in men. Furthermore, there is only one comparable study specifically examining the role of caffeine on muscular strength and muscular endurance in female participants (Goldstein et al., 2009). In this study only upper body muscular strength was considered and no testing was performed to look at the effects on lower body performance. Consequently, it is recognised that there is a need for further investigation into female athletes, caffeine and muscular performance.

1.3.3 Naturalistic Doses

There is some evidence to suggest that the amount of caffeine found in a strong cup of coffee, while not exceeding the limits set out by the International Olympic Committee, may be more than enough to enable an athlete to experience the physiological effects available from caffeine (Wiles, Bird, Hopkins and Riley, 1992). However there are limited published studies to support this and currently no studies exclusively supplementing caffeine in the form of coffee using a low absolute dose.

1.4 Aims and Objectives

This study aimed to investigate the acute effects of an absolute dose of caffeine, orally ingested in the form of coffee, on muscular strength and muscular endurance. A secondary aim of the study looked at whether habitual coffee drinkers had a lessened effect to caffeine compared to the non-habitual drinkers. The participants ingested a single serving of coffee (1.8g), equivalent to 61 Milligrams (mg) of caffeine 1-hour (hr) before completing their three repetition maximum (3RM) and repetitions to failure for bench press and leg press exercises.

The objectives of this study were to observe whether caffeine impacted the maximum weight lifted and maximum repetitions performed in female participants.

1.5 Hypothesis

The first hypothesis was that a single serving of coffee would have no significant effect ($P \leq 0.05$) on participant's estimated one repetition maximum (1RM) for bench press or leg press, compared with the placebo trial. Additionally, the second hypothesis anticipated that ingesting a single serving of regular coffee would cause a significant ($P \leq 0.05$) increase in repetitions to failure for both bench and leg press exercises compared to placebo. It was also hypothesised that the habitual coffee drinkers would experience less of an effect to caffeine as

CHAPTER TWO

REVIEW OF LITERATURE

2.0 REVIEW OF LITERATURE

2.1 Caffeine and Performance

Multiple studies demonstrate the ergogenic ability of caffeine for endurance exercise and aerobic capacity. Pasman et al, (1995) used nine well-trained male and female cyclists to test the effect of different dosages of caffeine on endurance performance. Doses used were 0, 5, 9, 13 mg/kg body weight. After ingesting caffeine or placebo subjects cycled to exhaustion at 80% of their maximal oxygen uptake on a cycle ergometer. A significant increase in endurance performance was found for all caffeine tests compared to placebo (endurance time 47 + 13, 58 ± 11, 59 ± 12 and 58 ± 12 min for 0, 5, 9 and 13 mg/kg body weight, respectively).

In another study using two 250mg doses of caffeine, Ivy et al. (1979) concluded an increase of 7.4% total work done during two hours of cycling with caffeine compared to placebo. This complies with data from Costille et al. (1978) where subjects cycled to exhaustion and found exercise time was 20% longer with coffee (caffiene dose = 330mg) vs placebo and several other reports not limited to cycling. After ingesting 6 or 9 mg/kg of caffeine vs. placebo, elite rowers were significantly faster rowing 2,000m (-1.2% time) (Bruce et al, 2000) and in a different study sprint swim performance was significantly enhanced in trained but not recreational, swimmers after ingestion of 250 mg of caffeine (Collomp et al, 1992). The vast research finding caffeine to have a positive effect on endurance performance explains why it has long been used in sport to mask fatigue and increase endurance.

2.2 Caffeine and Muscular Performance

Muscular performance defines the way in which muscles operate and includes components of strength, endurance, power and motor control. Each characteristic of muscular performance plays an important role to the correct functioning of the muscle. There is evidence for a number of effects of caffeine directly on skeletal muscle and there are proposals for effects on the central nervous system affecting the higher motor centres (Spriet, 1997; Graham, 2001). Research regarding the effects of caffeine supplementation on muscular strength and muscular endurance is still emerging and data results of published studies are equivocal (Williams, 1991) with some studies indicating a benefit and others demonstrating no change in performance.

2.2.1 Effect of Caffeine on Muscular Strength

As mentioned, caffeine is a stimulant and has a direct effect on muscle contraction. It does this by stimulating the release of calcium from its storage sites in the muscle cells, enabling calcium to stimulate muscle contraction more effectively (Bean, 2001).

A study by Beck et al, (2006) looked at the effect of a caffeine supplement (dose=2.4mg/kg) on resistance trained males and found a significant increase (+2.1kg) in 1-RM bench press but no change in lower body performance, determined by 1-RM leg extension exercise and variables recorded from a Wingate test. Beck concluded caffeine has an inadequate effect on lower body resistance exercise but a significant ergogenic effect on upper body strength. Similarly to the latter of Becks findings, a study by Woolf et al, (2008) revealed enhanced bench press performance, however Woof also observed an increase in peak power in elite male athletes following caffeine ingestion.

2.2.2 Effect of Caffeine on Muscular Endurance

In a study by Jacobs et al. (2013) examining muscular endurance rather than muscular strength they found that in 13 strength training men there was no difference in any parameter of muscular endurance after ingesting caffeine at 4mg/kg or placebo, tested out on bench press and leg press to fatigue. This opposes the results by Astorino et al (2008) by which the ingestion of a single 6 mg/kg dose of caffeine taken 1 h before bench press and leg press exercise resulted in an 11-12% increase in muscular endurance with caffeine compared to placebo. It has to be noted that the doses of caffeine between the two studies vary which could be a contributing factor to the conflicting results.

2.3 Caffeine Habits

There is great variation in response to caffeine on performance and metabolic functioning. This is evident for all groups of people studied; whether they habitually consume caffeine, small or large quantities, users who have withdrawn from caffeine and those who do not regularly consume caffeine.

2.3.1 Caffeine Abstinence

Following a prolonged period of daily caffeine consumption, changes in metabolic parameters can be detected which may dampen the ergogenic effect of caffeine (Roberstson et al., 1981). Previous studies (Hetzler, et al., 1994; Soeren and Graham, 1998) found that despite the presence of higher initial concentrations of caffeine, short-term periods of withdrawal from dietary caffeine prior to ingesting caffeine did not affect the maximal plasma caffeine concentration during exercise. This is consistent with the data available regarding caffeine metabolism in the liver (Kalow and Tang, 1993). Soeren and Graham (1998) did however find some modest differences in metabolic responses such as circulating free fatty acids and epinephrine concentrations between the withdrawal and no-withdrawal groups. They concluded that although there is not a certified time frame for caffeine abstinence, a four day period is needed to ensure caffeine is completely withdrawn from the body. Despite this, in an attempt to reverse these changes and re-sensitise the body to caffeine, the majority of caffeine studies for practicality reasons use an abstinence period between 12 to 48-hrs.

2.3.2 Caffeine Habituation

It has been proposed that habitual caffeine users may not benefit from the same ergogenic effect of caffeine as nonusers when ingesting the same dose of the drug (Davies and Green, 2009). As a result there have been many studies separating caffeine naïve and caffeine habituated participants in an attempt to understand the different effect caffeine has on the two groups. Dodd et al, (1991) found the nonusers were more responsive at rest in heart rate, ventilation and oxygen consumption but found no difference in exercise performance and both Van Soeren et al., (1993) and Bangsbo et al., (1992) found that users and nonusers differed only in the degree of increase in plasma adrenaline. These results comply with other similar studies that concluded no differences ($P > 0.05$) in performance between caffeine users and nonusers in aerobic and anaerobic exercises (Bell et al., 2001; Jacobs and Ellerington, 2001; Doherty, 1998; Doherty et al., 2001; Doherty et al., 2004; Bell et al., 1998; McLellan and Bell, 2004). Likewise Tamopolsky and Cupido (2000) found no differences between the two groups on the impact of caffeine on muscle force development. Subsequently, the differences produced by caffeine habits do not appear to be of substantial importance and instead more studies have started to investigate the differences in individual responsiveness to caffeine (Cook, Beaven, Kilduff and Drawer, 2012).

2.3.3 Caffeine Responsiveness

A few studies have investigated individual responsiveness to caffeine and it is evident that some individuals are more sensitive to the compound than others (Bell et al., 2000; Eissenberg and Griffiths, 1997; Evans and Griffiths, 1992; Nehlig et al., 1992). Therefore there is large variability between individuals for performance and metabolic responses to caffeine. Similar studies by Chesley et al., (1994) and Spriet et al., (1992) concluded that after ingesting caffeine, muscle glycogen sparing is greater in samples of untrained males than in trained males. There are few comparable studies in females to determine if the variability in response to caffeine ingestion is similar to that in males. Consequently, although mean data for a group of participants may predict an enhanced performance, it is not viable to reliably predict that the performance of a given individual will improve.

2.4 Caffeine Prescription; Timing, Dose and Form

Previous studies have looked at various methods of supplementing caffeine which has provided perceptiveness into suitable forms and doses of the compound.

2.4.1 Timing

Caffeine has a half-life of 4-6 hours which implies high levels of caffeine will remain in the blood for 3-4 hours after ingestion (Bell and McLellan, 2002). Despite this, the majority of studies supplementing caffeine have focused on the effects on exercise performance 1 hour after the ingestion of the compound. This protocol has been selected on the basis that the ergogenic effect of caffeine is related to the circulating level of the drug in the blood, which occurs 1 hour after ingestion (Bonati et al., 1982). Therefore it has been suggested as the optimal timing for enhanced performance as peak blood plasma concentrations are observed at this time.

2.4.2 Dose

Caffeine is a controlled or restricted substance with respect to the International Olympic Committee (IOC) with doses of at least 9 mg/kg or more required to exceed the maximal legal limit of 12 ug caffeine/ml urine (United States Olympic Committee guide to banned medications, 1988). However many studies have attempted to find the 'optimal dose' of caffeine to enhance performance and have concluded that a higher caffeine dose is no more beneficial than a lower performance enhancing dose (Graham, 2001). This is in agreement with Pasman et al. (1995) who compared the effects of 0, 5, 9 and 13 mg/kg caffeine on endurance performance. They found a significant increase in performance for all volumes of caffeine in comparison to placebo but no statistical differences were found in performance between the three quantities of caffeine used. This indicates that no dose-response relation between caffeine and performance was observed as increases in performance were comparable for both the moderate dose of 5mg/kg as well as the high dose of 13 mg/kg. A similar study by Graham and Spriet (1995) examining the effects of varying quantities of caffeine also found no difference between caffeine doses and suggests that a dose of 3 to 6 mg/kg is optimal. From previous literature it is not clear the minimal doses of caffeine necessary for an ergogenic effect on performance and the majority of research has used caffeine doses relative to body mass as opposed to absolute volumes in an attempt to reduce variability in responses.

2.4.3 Form

Caffeine is commonly consumed in many foods, beverages and over the counter medications with coffee being the most conventional mode of caffeine ingestion (Arnaud, 1993; Conlee, 1991). However with regards to research, the form in which caffeine is ingested and its effect on exercise metabolism has not been thoroughly investigated and explanations for the results are ambiguous.

2.4.3.1 Caffeinated Coffee Versus Anhydrous Caffeine

One of the most acknowledged studies examining the effect of different forms of caffeine is by Graham, Hibbert and Sathasivam (1998). Graham and his colleagues directly compared the effects of; caffeine capsules plus water, regular coffee, decaffeinated coffee, decaffeinated coffee plus caffeine in capsule form and placebo on aerobically conditioned runners. They found that only the pure caffeine resulted in an enhanced endurance effect despite all of the caffeine treatments ending with the same plasma caffeine concentration, and therefore proposed coffee may be less effective than anhydrous caffeine at increasing work capacity. Other studies have compared regular coffee or decaffeinated coffee with caffeine added to it against decaffeinated coffee (Butts and Crowell, 1985; Casal and Leon, 1985; Costill et al, 1978; Trice and Haymes, 1995) but results have been inconclusive. (Butts and Crowell, 1985, Casal and Leon, 1985) found very limited or no improvement in performance whilst (Costill et al 1978; Trice and Haymes, 1995) have shown the caffeinated beverage to have an ergogenic effect.

However none of these studies where looking at ingesting caffeine independent of coffee, which is where the rational for the study by Graham et al. (1998) came from. In the original work by Costil, Dalksy and Fink (1978) they found an improvement in endurance performance of 21% using decaffeinated coffee plus caffeine compare with decaffeinated coffee. Graham et al. (1998) decided to imitate the study design but administered caffeine independent to coffee. They found greater improvements, 28-43%, in endurance for similar exercise intensities. As already mentioned, the times to peak plasma caffeine concentrations achieved were equal for both the regular coffee and caffeine groups meaning differences in caffeine absorption could not be the reason for the findings. One possibility to explain the difference is that one or more of the various additional compounds in coffee may antagonise the actions of caffeine, reducing its ergogenic properties (Arnaud, 1993; Stavric, 1992).

2.4.3.2 Caffeinated Coffee Versus Decaffeinated Coffee

There are fewer studies solely comparing the effects of caffeine on performance between regular coffee and decaffeinated coffee. In a study by Wiles et al. (1992) ten participants consumed 3g of regular coffee and 3g of decaffeinated coffee as placebo, to examine the effects on running time. Their results indicated a faster running time, significantly faster run speeds and eight of ten participants had increased VO2 values. Similarly in a more recent study, Demura et al. (2007) compared the effects of coffee and decaffeinated coffee on submaximal cycling but found the only significant difference between the trials was a decreased rate of perceived exertion (RPE) for the caffeinated coffee treatment. An advantage of dispensing caffeine in this way, especially if low doses are being administered is the reduced psychological effect on the participant. It is very hard to distinguish the difference in taste between the caffeinated and decaffeinated coffee as opposed to adding caffeine to water or any other solutions.

2.5 Muscular Strength and Endurance, and Realistic Doses, as a Logical Progression in Research

Although caffeine has been identified as a potential ergogenic substance to aid sustained maximal endurance activity and also shown effective for enhancing time trial performances, there are limited research studies examining the effects of caffeine on maximum voluntary contraction and endurance, and none of which use low absolute doses. Therefore it would be beneficial to conduct further research into the effects of caffeine on muscular strength and endurance, in an attempt to identify further ergogenic functioning.

2.5.1 Defining Muscular Strength and Endurance

Muscular strength is defined as the maximal ability of a muscle to contract and generate force or the maximum load that can be lifted during a single isotonic contraction. Muscular endurance is the ability of a muscle to resist fatigue and can be defined as the maximum duration that a set submaximal isometric force can be maintained or the maximum number of isotonic contractions that can be performed while using a set submaximal load (Warren et al., 2010; Hanney et al., 2010). Definitions such as these allow specific strength and endurance tests to be validated.

2.5.2 Caffeine as an Ergogenic Substance for Muscular Strength and Endurance Work

Based upon the above definitions of muscular strength and endurance, it is evident that a variety of sports, as well as everyday tasks, require these components of fitness. Research has indicated a lack of understanding regarding the effects of caffeine on muscular performance, especially in female athletes and a lot of the results are inconclusive with further studies needed to support their findings. The documented literature investigating the acute effects of caffeine ingestion on dynamic muscular strength and muscular endurance is insufficient to draw robust conclusions. It is an important area to investigate as there are a large number of athletes who could potentially benefit with further research. Consequently, it would be beneficial to undertake research concerning the effects of caffeine on both upper body and lower body in females from a variety of sporting backgrounds.

2.5.3 Validated 1RM Protocols

To measure participant's muscular strength and endurance, it is important to adopt a recognised protocol in order to obtain valid and reliable results and to produce comparable results with other studies. A one repetition maximum (1RM) is the maximal amount of weight or resistance that can be lifted through the entire range of motion for a single time in a given movement. By definition, this is a good indication of muscular strength (Kraemer, Fleck and Deschenes, 2012) and is the most frequently utilised approach to evaluate muscle strength (Amarante do Nascimento et al., 2013).

However, while measuring 1RM directly would be the most accurate method of obtaining maximal strength results, it is not considered safe for untrained populations and can be very fatiguing which may affect the results of the muscular endurance test. As a result there are several studies that have developed equations to predict 1RM, derived from the performance of a specific relative submaximal load such as a 3RM (Abadie and Wentworth, 2000; Brzycki, 1993; Cosgrove, 1997; Dohoney et al., 2002; Kravitz et al., 2003; Mayhew, Arnold and Bowen, 1992; Morales and Sobonya, 1996). Based on the number of completed repetitions, regression analysis is performed and equations are developed in an attempt to predict the 1RM (Carpinelli, 2011). Therefore, for the present study 3RM will be tested using the same guidelines as set by the National Strength and Conditioning Association for testing 1RM (Miller, 2012). and 1RM will be estimated by methods of Baechle and Earle (2000).

The American College of Sports Medicine recommends using the bench press exercise to test upper body strength and leg press for lower body strength. Both exercises are multiple joint movements that use dynamic strength and force, making them good indicators for upper and lower body strength (Harman and Pandorf, 2000).

2.5.4 Naturalistic Doses of Caffeine

The minimal, effective dose of caffeine required to enhance performance has not yet been established. While caffeine doses ranging from 5-9 mg/kg have commonly been studied, it has been shown (Graham and Spriet, 1995; Kovacs et al., 1998) that doses as low as 2-3 mg/kg are effective. No one has conducted a similar comparison for resistance exercise. Despite the majority of commercially available caffeine supplements and high caffeine content beverages such as coffee and energy drinks, providing an absolute dose of caffeine, administering a dose relative to body mass and using anhydrous caffeine appears to be the more common method adopted by researchers. Irwin et al. (2011) proposes this should increase research design validity. Although this is an important factor that needs to be taken into consideration when examining the effect of caffeine, using a relative dose as opposed to absolute dose is far more impractical for real life situations and makes it difficult to interpret whether the results from previous studies would be transferable in more realistic circumstances. There is currently no literature examining the effects of a manufactures recommended serving size of caffeine containing coffee, which is a much more realistic dose and form of caffeine than that used in previous studies. Therefore it is important to examine the effects of realistic doses of caffeine as an easier way for athletes to implement it into their diet/training regime, if found to be beneficial.

2.6 The Rationale of the Present Study

Therefore, as there was limited research which linked caffeine, muscular performance and female athletes, the fundamental aim of this investigation was to examine the effects of caffeine on muscular strength and endurance in female participants. Low, absolute doses of caffeine were administered as further research in this area is necessary (Wiles, Bird, Hopkins and Riley, 1992). The hypotheses indicated that a single serving of regular coffee, containing 61 mg caffeine would have no effect on participants 1RM but would significantly ($P \leq 0.05$) increase repetitions to failure in upper and lower body exercises. A secondary hypothesis proposed caffeine habituated participants would experience less of an effect to caffeine as caffeine naive participants.

CHAPTER THREE

METHODOLOGY

3.0 METHODOLOGY

3.1 Research Design

Participants were divided into two groups and treatment order (caffeine or placebo) was randomly assigned to each group. A single-blind crossover design was then used; with trials separated by one week in order to minimise subject fatigue.

3.2 Participants

Fourteen female participants (age 21.1 ± 0.7 years, body mass 65.9 ± 9.5 kg, stature 165.4 ± 7.4 cm) were recruited for the study. They were informed of the procedure and nature of the study as well as being told that the study is completely voluntary and all results collected would be confidential. Males were excluded from participation as the purpose of this study is focusing on the effect on female athletes only. Participants were required to fill out a health-history questionnaire (see appendix C) prior to taking part in any testing; this included whether or not they were currently or have been recently using oral contraception as data (Lane, Steege, Rupp and Kuhn, 1992) show that menstrual cycle or oral contraceptive use may delay the clearance of caffeine. It also included their habitual caffeine consumption as previous studies have proposed habitual caffeine ingestion can potentially result in a caffeine tolerance (Goldstein et al., 2010) and consequently may influence the results of this study.

3.2.1 Training Status

Participants were collegiate athletes from varying sporting backgrounds. All had a minimum of one year's resistance training experience and were familiar with the bench press and leg press exercises. This eliminated the need for a familiarisation period prior to testing.

3.2.2 Caffeine Habits

Participants were grouped into habitual coffee drinkers and non-habitual drinkers based on the answers they provided on the health-history questionnaire relating to daily caffeine consumption. Participants were classed as habitual coffee drinkers if they consumed one or more cups of coffee a day whilst the non-habitual drinkers were represented by the participants who do not drink any coffee.

3.3 Informed Consent and Ethical Approval

All participants were made fully aware of the caffeine doses that were to be used and the benefits and risks to taking part in the study. They were presented with a detailed information sheet (appendix A) relating to the study before providing written informed consent (appemdix B), whilst all experimental procedures were approved by the University Institutional Research Ethics Committee.

3.4 Monitoring of Exercise Status and Dietary Intake

Participants were asked to complete 24 h diet and exercise recalls before each trial, and were required to follow the same diet on the day preceding each trial. They were asked to refrain from caffeine intake 48 h pre-visit in an attempt to resensitise the body to the acute effects of caffeine (Doherty and Smith, 2004). To aid this they were given a list of drinks and foods that contain caffeine, as well as provided a list of common over the counter medications that contain caffeine (see appendix A). Participants were also required to abstain from intense exercise in the 24 h preceding each trial.

3.5 Treatment Ingestion

An absolute dose of regular caffeinated coffee or a placebo consisting of decaf coffee was provided to participants in identical sachets and consumed 60 minutes prior to testing. This is shown to be the optimum time of administration of caffeine to enhance performance as peak absorption of caffeine is achieved and plasma concentrations can approximate a maximum level in 60 minutes. (Graham, 2001). The coffee and placebo supplements selected for this study were Nescafe Original and Nescafe Original Decaff. No previously known studies have investigated the effects of this coffee on exercise performance. The caffeinated coffee dose for all participants was 1.8g; which equivalents to 61 mg caffeine. This complies with ethical regulations and is the manufactures recommended single serving dose. The decaffeinated coffee placebo was provided in the same dose (1.8g). One week later, participants ingested the other treatment and repeated the identical exercise protocol.

3.6 Anthropometric Measurements

Stature and body mass measurements of participants were collected prior to the testing using a portable SECA stadiometer (Model 321, Vogel & Halke, Hamburg, Germany) and SECA digital scales (Model 770, Vogel & Halke, Hamburg, Germany).

3.7 Exercise Protocol

Participants were required to carry out the exercises on three occasions. The first occasion was: (1) To familiarise participants with the exercise protocol and (2) to test 1-RM and repetitions to failure without ingesting caffeine or placebo in order to gain baseline measurements for each participant; this was then used to determine any significant changes in performance. The subsequent two occasions were following the ingestion of the caffeine and placebo.

Determination of 1-RM was ensued indirectly using the participant's 3RM and the methods of Baechle and Earle (2000). 3RM represented the maximum weight lifted three times with proper form and was used over testing 1RM directly as a result of the participants training status, and to reduce the potential risk of injury.

Testing took place in the Diagnostic Gym at the National Indoor Athletics Centre (NIAC). Participants initially warmed up by jogging two laps around the NIAC running track. Subsequent to this, each subject's 3RM bench press and leg press was determined following the guidelines set by the National Strength and Conditioning Association (Miller, 2012). Participants completed a warm-up set on the standard barbell bench press using a light resistance that easily permitted 5-10 repetitions, followed with a one-minute rest period. The determination of the 3RM then started with the first load set at 50% of the participant's approximate 1RM, allowing 5 repetitions. Participants were given a two-minute rest before the load was increased to make the exercise more difficult to perform; this was dependent on the ease of the previous set. This process continued until the bar was loaded with the maximum weight at which the participant could perform three repetitions using the appropriate exercise technique. Participant’s 3RM was recorded and 1RM calculated using the following equation, by Baechle (2000):

$$\text{Weight} \times (1 + (0.033 \times \text{Number of repetitions}))$$

Previous testing (Astorino, Rohmann and Firth, 2008) showed when leg press was performed before bench press exercise there was no change in 1RM. However, participants reported being a lot more fatigued after the leg press exercise and therefore for this reason, leg press followed the bench press exercise. Participants were given verbal encouragement throughout the protocol.

As an index of muscular endurance, the bar was loaded to 60% of participants 1RM shortly after 1RM determination and participants completed repetitions to failure. Approximately 5-10 min later, participants were asked to begin the leg press exercise following the same protocol. They returned one week later and repeated the identical protocol after ingestion of the other treatment.

After completing the tests participants were asked whether they thought they have consumed the caffeinated coffee or placebo to identify any possible psychological effects.

3.8 Statistical Analysis

Raw data was analysed using SPSS Statistics Version 20 (SPSS, IBM corp., New York) using a series of paired T-Tests; which serves the purpose of comparing the means of two samples related to the same group of participants (O'Donoghue, 2012), to examine differences in all indices of muscular strength and endurance between caffeine, placebo and control trials. A probability of 95% ($P \leq 0.05$) was accepted to determine statistical significance and data was reported as a mean ± SD. Paired T-Tests were also employed to establish whether habitual coffee drinkers experienced reduced effects from caffeine. Graphical data was completed using Microsoft Excel 2010 package.

CHAPTER FOUR

RESULTS

4.0 RESULTS

Originally sixteen participants agreed to partake in the study, however six of these participants did not attend all of the three required testing sessions and consequently their data was excluded. As a result, an additional four participants were recruited to take part in the study, giving a total of fourteen female participants (age 21.1 ± 0.7 years, body mass 65.9 ± 9.5 kg, stature 165.4 ± 7.4 cm). For all the data obtained the population observed was normally distributed (P > 0.05).

4.1 Muscular Strength

4.1.1 Bench Press 1RM and Leg Press 1RM

Table 1 below summarises the mean 1RM for participant's bench press and leg press scores. There was no difference in participants 1RM bench press or 1RM leg press between the control, decaffeinated or regular coffee trials (standard error of difference = 0), statistically proving caffeine had no effect on maximal strength during upper body or lower body resistance exercise.

Table 1: Mean (± SD) values for participants 1RM (kg) control, placebo and regular coffee bench press and leg press trials (n = 14)

Trial	Bench Press	Leg Press
Control, Placebo and Caffeine	42.39 (7.25)	112.26 (38.73)

4.2 Muscular Endurance

4.2.1 Bench Press Repetitions to Failure

Figure 1 demonstrates a significant difference (P = 0.001) between the decaffeinated and regular coffee trial for the bench press exercise (20 ± 3 reps vs. 22 ± 3 reps). To support this, the control trial was also tested and similarly to the decaffeinated coffee and regular coffee test results, there was a significant difference between the control and regular coffee trial (P = 0.001) (20 ± 3 reps vs. 22 ± 3 reps). As expected there was no significant difference (P = 0.055) between the control trial and decaffeinated coffee trial (20 ± 3 reps vs. 20 ± 3 reps).

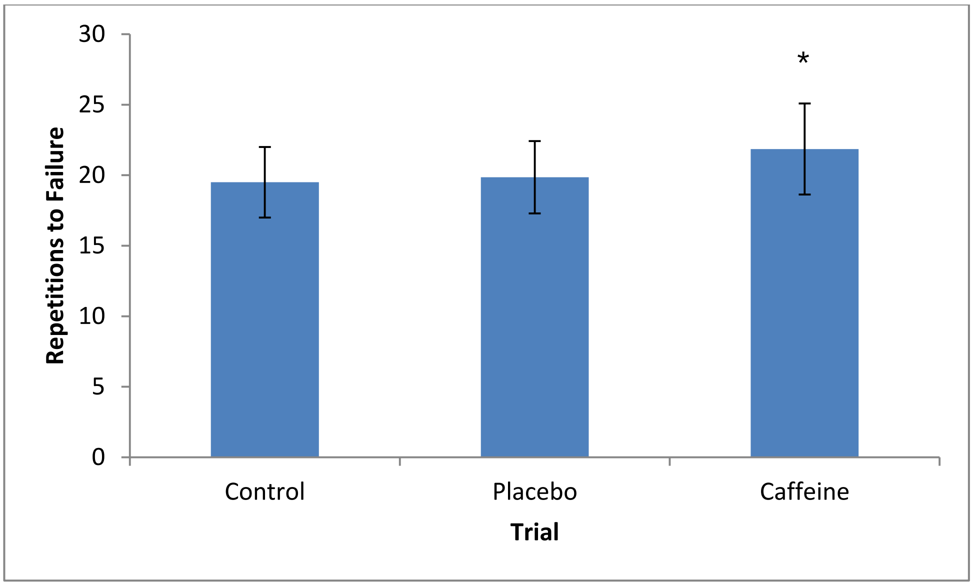

Figure 1: Mean (± SD) values for bench press repetitions to failure during the control, placebo and regular coffee trials (n = 14)

* denotes a significant difference (P ≤ 0.05) compared with the placebo and control results

4.2.2 Leg Press Repetitions to Failure

Comparable to the results of bench press, Figure 2 illustrates a significant difference (P = 0.000) between the decaffeinated and regular coffee trial for the leg press exercise (23 ± 8 reps vs. 25 ± 8 reps). To support this, the control trial was once again tested and alike the decaffeinated coffee and regular coffee test results, there was a significant difference between the control and regular coffee trial (P = 0.000) (23 ± 8 reps vs. 25 ± 8 reps). As expected there was no significant difference (P = 0.054) between the control trial and decaffeinated coffee trial (23 ± 8 reps vs. 23 ± 8 reps).

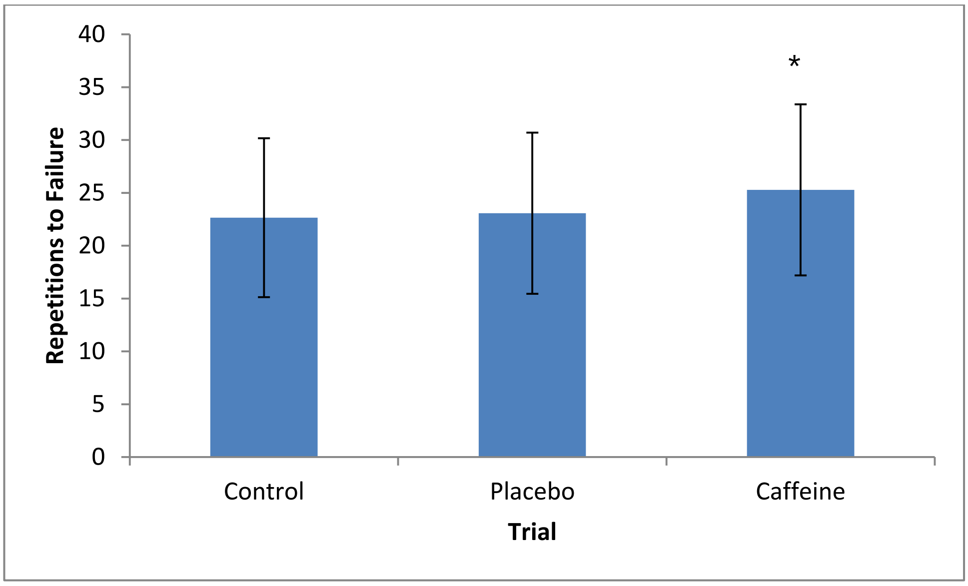

Figure 2: Mean (± SD) values for leg press repetitions to failure during the control, placebo and regular coffee trials (n = 14)

* denotes a significant difference ($P \leq 0.05$) compared with the placebo and control results

4.3 Habitual Coffee Drinkers versus Non-habitual Drinkers

As the standard error of difference between participant's 1RM bench and leg press between all three trials was equal to zero, a parametric test to determine a difference between habitual coffee drinkers and non-drinkers results was only run for repetitions to failure.

4.3.1 Bench Press

There was no significant improvement ($P = 0.052$) between the decaffeinated coffee and regular coffee trials for the non-habitual coffee drinkers during bench press exercise. However, a significant improvement did existed between the habitual coffee drinkers decaffeinated coffee and regular coffee trials for the same exercise ($P = 0.006$).

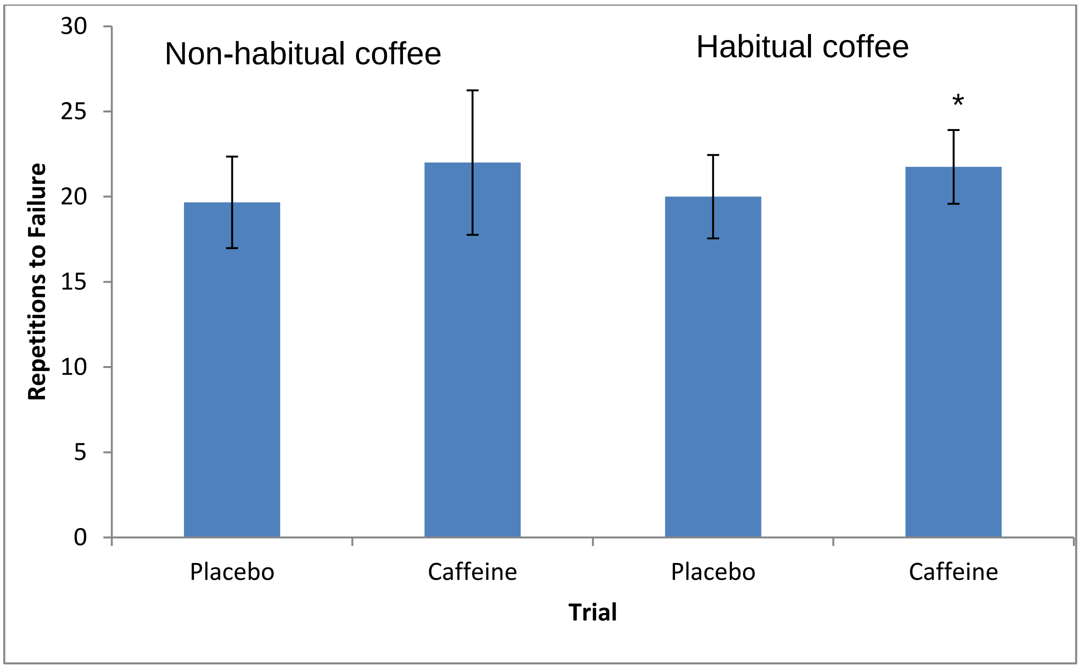

Figure 3: Mean (± SD) values for bench press repetitions to failure between decaffeinated and regular coffee trials of non-habitual and habitual coffee drinkers (non-habitual drinkers n = 6, habitual drinkers n=8)

* denotes a significant ($P \leq 0.05$) difference compared with placebo trial.

4.3.2 Leg Press

A significant improvement was seen in both the non-habitual ($P = 0.018$) and habitual ($P = 0.003$) coffee drinkers between decaffeinated and regular coffee trials for the leg press exercise demonstrated in Figure 4 below.

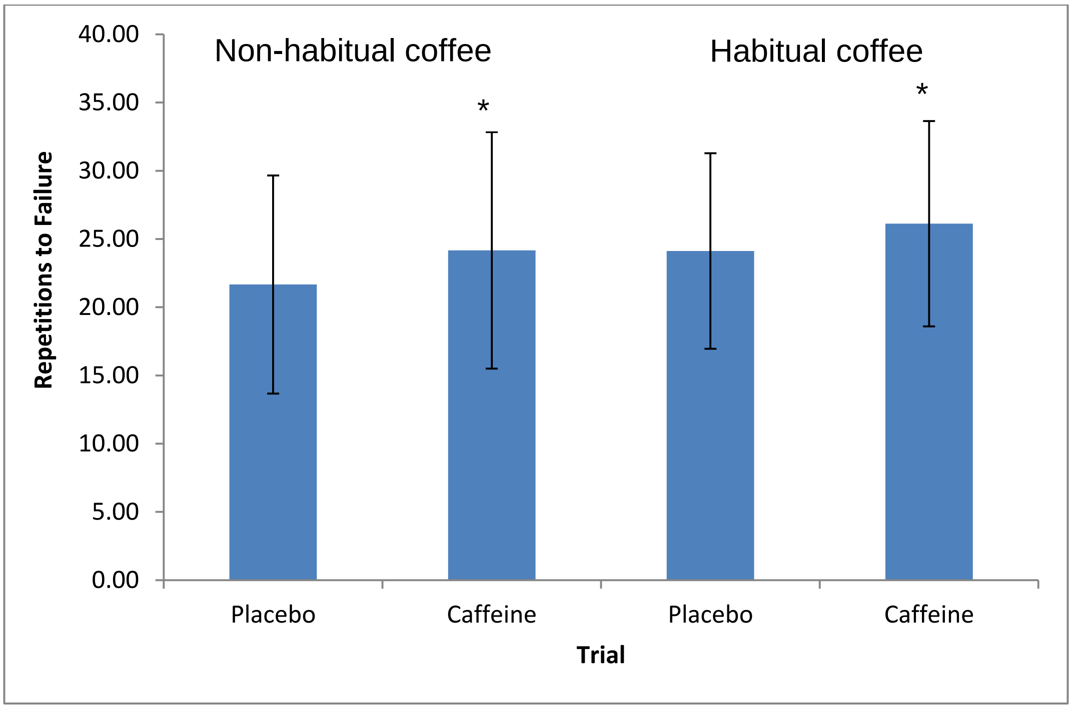

Figure 4: Mean (± SD) values for leg press repetitions to failure between decaffeinated and regular coffee trials of non-habitual and habitual coffee drinkers (non-habitual drinkers n = 6, habitual drinkers n=8)

* denotes a significant ($P \leq 0.05$) difference compared with placebo trial.

CHAPTER FIVE

DISCUSSION

5.0 DISCUSSION

The major finding of this study is that acute caffeine supplementation appears to be effective for enhancing muscular endurance performance in females, as demonstrated by a significant increase in bench press and leg press repetitions to failure. Caffeine supplementation at approximately 61 mg had no statistically significant effect on muscular strength.

5.1 Overview of the Aims, Objectives and Hypotheses

The study implemented a quantitative approach to the investigation and the primary aims of this study were to examine the effect of acute ingestion of caffeine on muscular strength and endurance in female athletes. The objectives summarised that 3RM and repetitions to failure should be investigated to establish whether a significant ($P \leq 0.05$) difference existed for the indices of strength between the control, placebo and caffeine trials. The hypothesises for the study proposed that a single serving of coffee (61 mg caffeine) would have no significant ($P \leq 0.05$) effect on participants 1RM in bench or leg press but would significantly ($P \leq 0.05$) increase repetitions to failure in both exercises. The secondary hypothesis suggested that the habitual coffee drinkers would experience less of an effect to caffeine as the non-habitual drinkers. The results of the study signify that the aims and objectives were accomplished, suggesting the design of the study was appropriate.

The first primary hypothesis was accepted as the standard error of difference between each trial was equal to zero. This complies with previous studies investigating the effects of caffeine that suggest caffeine has no significant ($P > 0.05$) impact on muscular strength (Astorino et al., 2008; Williams et al., 2008) but is in disagreement with other studies that have concluded caffeine to have a positive impact on muscular strength (Goldstein et al, 2010). The second primary hypothesis was also accepted as the calculated probabilities (P values) were less than 0.05, meaning caffeine had a significant ($P \leq 0.05$) effect on repetitions to failure. This is in agreement with previous literature looking at the effects of caffeine on muscular endurance (Astorino et al., 2008; Astorino et al., 2011; Woolf et al., 2008; Duncan et al., 2013). However, the secondary hypothesis was rejected as the habitual coffee drinkers had a greater significant ($P \leq 0.05$) difference between trials compared with the non-habitual drinkers. Physiological properties of participants should have been measured to make more comparable assessments to previous literature.

However the similar results between habitual and non-habitual groups are in agreement with those of past studies (Bell et al., 2001; Jacobs and Ellerington, 2001; Doherty, 1998; Doherty, Smith, Davison and Hughes, 2001; Doherty et al., 2004; Bell et al., 1998; McLellan and Bell, 2004).

The rest of the chapter will look at the findings of the study in more depth and try to provide logical explanations for the results. In addition the latter of this chapter identifies practical implications and limitations of the study before highlighting proposals for future research.

5.2 Muscular Strength

With regards to caffeine supplementation strength research is still emerging and publications of results from previous studies are ambivalent, with some studies indicating a benefit and others demonstrating no change in performance.

In this present study no difference was found between any of the trials for participants 1RM bench press or leg press scores (42.39 ± 7.25 kg and 112.26 ± 38.73 kg respectively), concluding caffeine had no effect on muscular strength.

This agrees with a recent publication by Astorino et al. (2008) that also found no significant difference between participant's caffeine and placebo trials for either bench press or leg press 1RM. Astorino and his colleagues implemented a similar research design using a randomized, double-blind crossover study. 22 resistance-trained men took part in the study and the caffeine supplement was equivalent to 6mg/kg bodyweight and ingested 1 hr before testing 1RM.

Likewise, Williams et al. (2008) used a double-blind, crossover study to examine the effects of caffeine (300mg) or caffeine plus ephedra (300mg + 60 mg) compared to a glucose placebo (300 mg) on resistance training performance. 9 resistance-trained male participants took part in the study and the supplement was taken 45 minutes prior to exercise. The researchers found no significant differences in performance between any of the three trials

Conversely the results from this study disagree with that of Goldstein et al. (2010). Goldstein and colleagues looked at the effects of caffeine, 6 mg/kg bodyweight, as opposed to placebo on upper body muscular strength tested by 1RM barbell bench press. 15 resistance-trained females were recruited for the study and supplement was ingested 60 minutes before testing. Results indicated a significant difference in performance between trials. However, albeit statistically different, the improvement was only slightly greater with the caffeine supplement (52.9 ± 11.1 kg vs. 52.1 ± 11.7 kg).

Furthermore a study by Beck et al. (2006) who investigated the effects of caffeine on upper body and lower body muscular strength in resistance-trained males, found that 201 mg caffeine consumed 1 hr prior to testing was effective for increasing bench press 1RM but did not produce a significant change in lower body strength.

The differences in outcomes between investigations that have looked into the effects of caffeine supplementation on muscular strength may be due to the different doses of caffeine used and varying levers of caffeine habituation. Therefore further research is needed to make a robust conclusion.

5.3 Muscular Endurance

There was a significant improvement between participant's decaffeinated coffee trial and regular coffee trial for the number of repetitions to failure for both bench press (20 ± 3 reps vs. 22 ± 3 reps) and leg press (23 ± 8 reps vs. 25 ± 8 reps). Concluding a regular single serving of coffee is sufficient to improve muscular endurance.

In the same study by Astorino et al. (2008) discussed above, upper and lower body muscular endurance was measured as a result of repetitions to failure at 60% of 1RM in bench press and leg press exercises. The researchers found a non-significant trend for the 60% of 1RM repetitions to failure to be higher in the caffeine trial compared to the placebo. A more recent study by Astorino (2011) of similar design looked at the effects of caffeine on muscular endurance, however this time, the exercise test comprised 4 sets of barbell bench press, leg press, bilateral row and barbell shoulder press to failure using 70 – 80% of 1RM. They found that caffeine had a significant ($P < 0.05$) effect on repetitions to failure for the leg press exercise but not on any of the upper body exercises ($P > 0.05$).

This is in contrast to the results of Woolf et al., (2008) who found the opposite body parts to be affected. Following the ingestion of 5mg/kg caffeine, highly conditioned male athletes completed bench and leg press repetitions to failure and the results indicated a significant increase in bench press performance but reported no statistically significant effect of caffeine on leg press performance.

The results of this study comply with a recent study by Duncan et al., (2013) who observed a significant increase in upper and lower body exercise performance after ingesting caffeine 1 hr before exercise. Duncan and his colleagues performed a double-blind, randomised cross-over study looking at the effects of caffeine (5mg/kg), as compared with placebo, on bench press, deadlift, prone row and back squat exercises to failure at an intensity of 60% 1RM. 11 resistance trained individuals (9 male, 2 female) took part in the study and the researchers found participants completed significantly ($P = 0.0001$) more repetitions to failure, in all exercises for the caffeine trial. Therefore there is evidence to suggest acute ingestion of caffeine is beneficial for resistance training.

5.4 Caffeine Habituation

There have been a few studies that have segregated caffeine naive and caffeine habituated individuals with most of the findings agreeing caffeine habits have little effect on responsiveness to caffeine. Similar to this study, Tamopolsky and Cupido (2000) examined the effects of regular caffeine consumption on skeletal muscle force. Twelve males took part in the study and a four day diet record analysis was used to classify participants as habitual ($n = 6$) or non-habitual ($n = 6$) users. A double-bind, crossover study was employed and a caffeine dose of 6mg/kg administered. There was no difference between the two groups on maximal voluntary contraction or peak twitch torque leading the researchers to conclude habitual caffeine users do not have a significantly different effect to caffeine as non-habitual users.

In the present study there was no significant ($P > 0.05$) improvement between the decaffeinated coffee and regular coffee trial for the non-habitual coffee drinkers during bench press repetitions to failure, whilst there was a significant difference observed between the two trials of the habitual coffee drinking participants. However, there were only six participants in the non-habitual group and although no statistical difference was reported the results were approaching significance ($P = 0.052$). Therefore if a larger sample size had been tested a significant difference between trials may have been evident. During the leg press exercise a significant difference ($P < 0.05$) between decaffeinated coffee and regular coffee trial existed for both the habitual and non-habitual coffee drinking groups.

Surprisingly the level of significance was greater in the habitual coffee drinking group compared to the non-coffee drinkers in both bench press and leg press (P = 0.006 vs. P = 0.052 and P = 0.003 vs. P = 0.018 respectively). Again, the small and different sample sizes may in part explain these results (habitual coffee drinking group n = 8, non-habitual drinkers n = 6) and as physiological properties of participants were not measured, for instance heart rate or blood plasma concentrations, it is not known if the non-habitual coffee drinkers may have been more responsive in other areas as to performance.

Similar studies by Dodd et al., (1991), Van Soeren et al., (1993) and Bangsbo et al., (1992) who measured these physiological responses to caffeine, found nonusers were more responsive at rest in heart rate, ventilation and oxygen consumption and found a difference in the degree of increase in plasma adrenaline.

Another consideration is how participants were categorised. Participants were assigned a group based on how they answered questions regarding daily caffeine consumption on the pre-testing health history questionnaire.

If participants answered yes to drinking one or more cups of coffee a day they were put into the ‘habitual coffee drinking’ group, whilst participants who claimed not to drink any coffee where placed in the ‘non-habitual’ group. Due to sample size only two caffeine habit characterised groups were created. This meant that the quantity of caffeine consumed on a daily basis amongst the habitual coffee drinking group varied greatly. Caffeine is also commonly found in many other beverages such as tea and sodas which was not accounted for in either group. This may have had a large influence on the results of this study and questions the reliability of the findings.

In addition, an absolute dose of caffeine was administered to all participants meaning it is possible that the participants in the non-habitual coffee drinking group, where less of an effect was observed, may have had a lower dose of caffeine relative to body weight compared to the relative dose of participants in the habitual coffee drinking group.

To conclude, the differences produced by caffeine habits do not appear to be of substantial importance and instead the differences in individual responsiveness to the supplement should be investigated

5.6 Mechanisms of Action

It has been suggested by Astorino et al (2008) that caffeine can delay the onset of fatigue by reducing motor unit recruitment. This may explain why caffeine was not able to improve singular maximal voluntary contraction as muscular contractile strength may have been inhibited. It would however, justify the ergogenic response observed in repetitions to failure. It has also been suggested that dampened perception of perceived exertion and pain perception might be an explanation for any possible enhancement of resistance exercise performance due to caffeine ingestion.

5.5 Practical Implications

The results from this study found that acute ingestion of coffee containing 61 mg caffeine 1 hr prior to exercise resulted in no significant muscular strength improvements. Based on this finding and past literature maximal strength during resistance-training might be improved by caffeine supplementation but few studies support this conclusion. The study did conclude that caffeine significantly improved muscular endurance, with more repetitions to failure being performed for the caffeine trial. However, not all previous studies comply with this conclusion. Therefore coaches or personal trainers should consider this information and may recommend a low dose of caffeine 1 hr prior to exercise to athletes as a way of improving muscular endurance during resistance training but advise athletes to not heavily rely on caffeine as a mechanism of enhancing performance until further research is conducted and a robust conclusion made in regards to the ergogenic potential of caffeine.

Habitual coffee drinkers were no less susceptible to the beneficial properties of caffeine compared to non-habitual drinkers. However there are a few factors that may have influenced these results, including whether any caffeine had been ingested prior to the study supplementation.

Subsequently, a practical implication found in this study to consider regarding caffeine consumption is not being able to directly monitoring the 24 hr abstinence period. Participants were asked to refrain from high caffeine content food and beverages 24 hrs prior to testing and to follow the same diet in the 24 hrs proceeding the subsequent testing session. There is no guarantee that participants followed these instructions or to what extent if they did, especially considering caffeine is commonly found in many typical everyday foods and drinks (Del Coso et al., 2011). This is a concern as caffeine consumption prior to any of the trials may influence the results and may have caused a varying caffeine abstinence period between participants. Similarly participant were asked to refrain from strenuous exercise 24 hrs prior to testing but again there was no guarantee that all participants followed these instructions to the same level, meaning some participants may have been prematurely fatigued during one session compared to another.

Another practical implication to consider is that an absolute dose of caffeine was tested. Therefore individual responses may be different as some participants will have received a higher dose of caffeine relative to body mass compared to others.

5.6 Strengths and Limitations of the Study

Strengths of the study are that the caffeine and placebo supplements used were identical in flavour, making it very difficult if not impossible to distinguish which treatment had been ingested. None of the fourteen participants were correctly able to identify which supplement they had been given after each trial. This eliminated the potential psychological ‘placebo effect’ that may have occurred if the caffeine supplement had not been masked.

However, many limitations to the present study have been recognised that may have influenced the results of the study. Sample size appears to be one of the more fundamental issues, especially when concerning habitual and non-habitual coffee drinkers. A relatively small sample size (n=14) was used and when looking at the difference between habitual coffee drinkers and non-habitual drinkers this sample was split into a further two groups (n=6 and n=8). As previously discussed, the small sample size could have influenced the insignificant ($P > 0.05$) response to caffeine found in the non-habitual coffee drinking group. Consequently, a larger sample would be needed to draw more reliable conclusions.

The validity of Baechle and Earle’s, (2000) methods to estimate 1RM was considered another limitation. Testing 1RM directly would have been the most accurate measure of maximal muscular strength, however due to the participants recruited, 1RM derived from 3RM was a safer approach.

Furthermore, some of the participants were taking oral or parenteral contraception (n=8), however this was not taken into account in the design of the study as all participants followed the same protocol and ingested the caffeine at the same time prior to exercise which may have influenced some of the results.

A final limitation to the study was not measuring heart rate or utilising blood samples. To address the research question of this study it was not necessary to measure participant's heart rates. However it has been suggested that caffeine can significantly increase hear rate during exercise (Yeragani et al., 2005; Karapetian et al., 2008) and therefore it may have been useful as an insight into individual responsiveness of participants to caffeine. Blood samples were not utilised as once again it was not necessary to answer the research question and trained personnel are required to administer the blood sampling and subsequent analyses.

5.7 Future Study Directions

Consequently, future studies should address the limitations highlighted in this study by the following suggestions. A larger sample size should be used to improve the reliability of results and individual participant responsiveness needs to be investigated to establish whether they are responders to caffeine or not, as some participants may benefit from caffeine supplementation more than others.

As menstrual cycle and contraception has the ability to delay caffeine clearance, future research should take this into consideration and possibly experiment ingesting the caffeine at different time intervals prior to testing.

Where possible, future studies should implement blood sampling procedures into the protocol as it would allow plasma concentrations to be identified, providing additional quantifiable data to support the study.

Furthermore, another area of research that should be considered is the effects of caffeine on muscular endurance between trained and untrained participants, as most of the literature has examined resistance-trained participants only. In addition, future studies should look at the effects of caffeine on muscular endurance in the upper body compared to lower body as past literature in this area has produced conflicting results.

Finally future research should research should monitor the caffeine abstinence period more closely and if an absolute dose of caffeine is going to be implemented the varying differences in relative dose to body mass between participants should be accounted for.

CHAPTER SIX

CONCLUSION

6.0 CONCLUSION

To conclude the present study, the aims of this investigation were effectively achieved by examining the short-term effects of orally ingesting caffeine on muscular performance in females. The foremost finding was that caffeine had no effect (standard error of difference = 0) on muscular strength during any of the trials but did however have a significant ($P < 0.05$) ergogenic impact on repetitions to failure in upper and lower body exercises compared with placebo. As a result the primary hypotheses were accepted as it was predicted that no difference would be seen in 1RM performances following caffeine ingestion but an increase in repetitions to failure was anticipated. A further finding indicated that caffeine habituated participants were no less susceptible to the ergogenic properties of caffeine as caffeine naive participants. Statistically, the habitual coffee drinking group evidently demonstrated a greater significance between trials when compared with the non-habituated group's results. Consequently the secondary hypothesis was rejected, as this had proposed that the habitual coffee drinkers would experience less of an effect to caffeine as the non-habitual drinkers.

Based on the findings and limitations highlighted in this study, future studies should implement a larger sample size and blood sampling should be utilised in order to obtain more reliable, quantifiable data. Individual responsiveness to caffeine should be investigated and the caffeine abstinence and participant's diets should be monitored more closely before testing to provide more accurate results. In addition studies should investigate the difference in effects between un-trained and resistance-trained participants and similarly a comparison between the effects on upper body and lower body need further investigation.

To summarise, a single serving of regular coffee does not appear to have any effect on muscular strength but was able to enhance muscular endurance. There is limited research available on the effects of coffee as a form of caffeine supplementation to enhance performance; therefore more is needed to support the findings of the current study and previous research.

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APPENDICES

APPENDIX A

PARTICIPANT INFORMATION SHEET

PARTICIPANT INFORMATION SHEET

Project: Is coffee an effective pre workout drink? – *The effect of ingesting caffeine on one-repetition maximum muscular strength and muscular endurance.*

Background

This project is an attempt to understand the effectiveness of using coffee as a pre-workout supplement.

There are two areas that the project will examine:

(i) the effect of acute ingestion of caffeine on one-repetition maximum (1-RM) performance

(ii) if muscular endurance is altered with caffeine ingestion.

Upper body strength and endurance will be assessed using the bench press exercise and lower body muscular strength and endurance will be measured using the leg press exercise.

Your participation in the research project

Why have you been asked?

You will have volunteered to take part in this study, providing you meet the demographic participant requirements.

What would happen if you agree to take part?

If you agree to take part in this study you will be asked to refrain from eating foods and drinks high in caffeine 24 h pre testing, and to refrain from strenuous exercise 24 h pre testing. You will be required to take part in testing on three occasions; the first visit will be to determine baseline strength and endurance. On the subsequent days of testing you will be provided with a drink, one week containing caffeine and one week a placebo – in a randomly assigned order. You will then be asked to perform your 3RM bench press, immediately followed by repetitions to failure at 60% of your 1RM. After the bench press exercise you will be asked to follow the same procedure for the leg press exercise. Please wear suitable clothing to perform the exercises, for example, shorts and trainers.

Are there any risks?

There are no significant risks to your health in taking part in this study but as with any strength and resistance training exercises there is the possibility of injury. To minimise the potential risk of injury you will be taken through an appropriate warm up prior to testing, given instructions on how to perform the exercises correctly and you will be supervised and spotted at all times whilst performing the exercises. There are possible side effects associated with caffeine consumption, however these are more commonly observed with higher dosages of caffeine.

Your rights

You have the right to withdraw from participation at any point in the study with no consequences.

What happens to the results of the study?

The findings concluded from the statistical analysis of the data collected will be put into a discussion identifying key findings from the study. You will remain completely anonymous throughout the study and will not be identifiable from your specific results.

Are there any benefits from taking part?
Yes, if you would like to find out the results of the study you can be informed of these once the investigation is complete. You may use this information to determine if coffee is an effective pre-workout supplement for yourself and therefore implement or remove it from your current diet if you so wish to do so. Participation in the study is completely free and supplements required to be ingested will be provided.

What happens next?
With this information sheet you'll find a participant consent form. Once you have fully read and understand this information sheet you a required to sign the consent form before we can confirm your involvement in the study. By doing so you are agreeing that you are fully aware of what is expected from yourself in the study and understand that you have the right to withdraw at any time.

How we protect your privacy:
Throughout and following the study your privacy will be respected with careful precautions put into place to ensure you cannot be identified from any of the information we have about you. Your identity will remain anonymous and all the information about you and consent forms will be stored securely.

Further information
If you would like any further information regarding the study or if you have any questions about the research and how it is intended to be conducted, please contact myself.

Gabrielle Thomas

Telephone: 07951964424
Email: st20009851@outlook.cardiffmet.ac.uk

Here is a list of foods, drinks and medication containing caffeine, please refrain from consuming these in the 24 h preceding testing. Please also keep a food diary for the 24 h preceding testing and follow the same diet 24 h preceding the following testing session.

Drinks and food containing caffeine:

- Tea
- Green tea
- Coffee
- Energy drinks
- Coke and other soft drinks
- Chocolate
- Caffeinated snacks

Over the counter medication containing caffeine:

- Cold remedies
- Diuretics
- Weight loss products
- NoDoz or Vivarin
- Excedrin Migraine
- Midol Complete
- Bayer Back & Body
- Anacin

Please also refrain from taking caffeine supplements or any other supplements that are intended to enhanced performance.

APPENDIX B

INFORMED CONSENT FORM

PARTICIPATION CONSENT FORM

Reference No:

Title of Project: Is coffee an effective pre workout drink? – *The effect of ingesting caffeine on one-repetition maximum muscular strength and muscular endurance.*

Name of Researcher: Gabrielle Thomas

Participant to complete this section: Please initial each box.

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

2. I understand that the participation is voluntary and that it is possible to stop taking part at any time, without giving a reason. I also understand that if this happens, my relationships with Cardiff Metropolitan University, or my legal rights, will not be affected. ☐

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

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

____
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 C

HEALTH HISTORY QUESTIONNAIRE

Health History Questionnaire – *please circle appropriate boxes*

1. Do you have any chronic medical conditions?

   No Yes please specify:

2. Do you take any regular medication?

   No Yes please specify:

3. What about stimulant medications used to treat Attention Deficit/Hyperactivity Disorder (ADHD) such as Adderall, Ritalin or Concerta?

   No Yes please specify:

4. Are you sensitive to caffeine or do you try to avoid eating or drinking foods that contain caffeine?

   No Yes please specify:

5. Are you taking any over-the-counter stimulant medications or supplements such as ephedrine (Sudafed, Herbal XTC, Energel) or caffeine supplements like Vivarin?

   No Yes please specify:

6. Do you regularly drink any energy or herbal drinks during the day that contain ephedra (Ma Huang), guarana, or caffeine such as allergy or sinus teas, Red Bull beverages?

   No Yes please specify:

7. The following is a list of caffeinated beverages. How many servings of each beverage do you consume in a typical day, on average?
   Cups of coffee:

   Cups of tea:

   Cans of caffeinated cola/diet cola:

   Cans of high caffeine soda (Mountain Dew, etc):

Bottles of caffeine water/juice:

Bottles of iced coffee or tea drinks:

8. Are you using oral or parenteral (injected) contraception?

   No Yes please specify: