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The Effects of Acute Caffeine Ingestion on Muscular Endurance and Perception of Pain and Effort in Resistance Trained Women

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THE EFFECTS OF ACUTE CAFFEINE INGESTION ON MUSCULAR ENDURANCE AND PERCEPTION OF PAIN AND EFFORT IN RESISTANCE TRAINED WOMEN

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The purpose of the study was to examine the effects of acute caffeine ingestion on muscular endurance and perception of pain and effort in resistance trained (RT) women. Eleven (RT) women participated in this double-blind, repeated measures study. A pre-assessment and two exercise sessions occurred. Exercise sessions entailed the same protocol, ingesting either caffeine or placebo. Participants completed three sets of repetitions (reps) to failure on leg extension (LE) and chest press (CP). Rating of Perceived Exertion (RPE) and pain perception (PP) were taken after each set. Two-way analysis of variance repeated measures revealed caffeine had no impact on reps on LE (p=0.530) and CP (p=0.922). No effect of caffeine on RPE was found on LE (p=0.499). There was a significance found in RPE on CP (p=0.035). No significance was found between caffeine and PP on LE (0.094) and CP (p=0.518).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Caffeine is one of the most widely used ergogenic aids, with approximately 90% of Americans consuming it daily. It can be found in a variety of compounds such as plants and dietary sources such as coffee, energy drinks, tea, chocolate, and soda (Astorino, & Roberson, 2010). Caffeine is commonly used by athletes to enhance performance. Doses as low as 3-9 milligrams per kilogram (mg/kg) of body weight have been shown to enhance performance, this is due to its effects of increasing alertness and giving individuals the ability to sustain activity for a longer period of time (Graham & Spriet,1996). Research supporting the benefits of caffeine on endurance performance is well known, while research supporting the benefits of caffeine on other modalities of exercise, such as resistance exercise is less clear and more research needs to be done on this topic.

The effect caffeine has upon endurance performance is well established. However, the mechanism of action that elicits a positive response on endurance performance is less clear. Dating back to the 1990's, the proposed physiological mechanism of caffeine on endurance exercise was presumed to be the increased availability of free fatty acids and enhanced fat oxidation resulting in glycogen sparing, and prolonged time to fatigue. Recent research has suggested that caffeine interferes with the reaction of the compound adenosine to receptors that assists the body in falling asleep, resulting in increased oxygen flow, alertness, and perception of effort (Kruskall & Miracle, 2009). Additionally, it has been demonstrated that caffeine ingestion results in enhanced performance related to muscular endurance, muscular strength, and power output. These types of activities are higher in intensity with a shorter duration, usually lasting less than 20 minutes (Astorino, & Roberson, 2010).

There continues to be inconsistent findings regarding the physiological effects of caffeine on resistance exercise as many studies on this topic have shown inconclusive results. One suggestion for the equivocal nature of previous research has been due to the lack of control of confounding variables in studies such as subject's dietary intake, hydration status, history of caffeine consumption, gender, and training status (Duncan & Oxford, 2011). Also, the majority of studies conducted on this topic have used either a combination of males and females, or have used only males as subjects. There are limited studies that have focused on females (Warren et al. 2010). Results are difficult to interpret when combining males and females, as studies have shown they respond differently to caffeine (Temple & Ziegler, 2011). Researchers have examined the effects of caffeine in females during endurance training, but studies focusing on the effects of caffeine on higher intensity exercise, such as resistance exercise in females is limited (Goldstein, Jacobs, Whitehurst, Tina, & Antonio, 2010) Ahrens, Lloyd, Crixell, and Walker (2007) reported no significant results in muscular endurance in females who were non habitual caffeine drinkers compared to caffeine drinkers. While Anderson et al. (2000) found a significant improvement of 2000 meter rowing performance among trained female rowers. Goldstein et al. (2010) found that caffeine enhanced muscular strength but not muscular endurance in resistance trained females at 60% of their one-repetition maximum. Control of gender and other confounding variables such as subject's dietary intake, hydration status, history of caffeine consumption, and training status is needed in order to establish the effect of caffeine on activities of higher intensity and shorter duration (Duncan & Oxford, 2011).

There are numerous physiological mechanisms that are believed to explain enhanced resistance exercise performance following the ingestion of caffeine. Caffeine may elicit sodium-potassium pump activity that enhances excitation contraction coupling (Richardson & Clarke, 2016). Caffeine is also believed to create an antagonizing effect on adenosine receptors, which leading to arousal, alertness, and blunted pain perception. It is also believed that part of the positive effects of caffeine ingestion on resistance exercise is due to a reduction of perceived effort and pain during the activity. In turn this enhances one's ability to perform more repetitions to fatigue (da Silva et al., 2015)

There are few studies that have reported the effects of caffeine in resistance-trained females (Goldstein et al., 2010). Furthermore, few studies that observe muscle pain have used females (Motl, O'Connor, Tubandt, Puetz, & Ely, 2006). Therefore, this study examined the effect of acute caffeine ingestion on muscular endurance and perceptions of pain and effort in resistance trained women

Statement of the Problem

The purpose of the present study was to determine the effects of acute caffeine ingestion on muscular endurance performance and perception of pain and effort in resistance trained women.

Research Question

What are the effects of acute caffeine ingestion on muscular endurance and perception of pain and effort in resistance trained women?

Hypotheses

1. Participants will perform more repetitions prior to reaching muscular fatigue after ingesting caffeine compared to the placebo.
2. Participants will have a lower rating of perceived exertion during performance of repetitions to failure after ingesting caffeine compared to the placebo.

3. Participants will have a lower perception of pain during performance of repetitions until failure after ingesting caffeine compared to the placebo.

Limitations

1. Participants may not have accurately reported their history of caffeine consumption and experience in resistance training.
2. Other confounding factors could have affected exercise performance such as dietary intake, amount of sleep, and stress.
3. Participants may not have abstained from pain medication as instructed prior to testing.

Assumptions

1. Participants had a resistance training history of at least 2 months, 2-4 days per week.
2. Participants abstained from caffeine at least 48 hours prior to testing.
3. Participants performed each exercise to the best of their ability and answered any subjective scales accurately and honestly.
4. Participants were not on oral contraceptives.
5. Participants were not taking any pain medications such as narcotics or NSAIDS at the time of testing.

Significance

It is well established that low to moderate doses of caffeine can have an ergogenic effect on endurance performance. The research to support the effect of caffeine on resistance training is less consistent. Previous studies that have examined caffeine intake and resistance training have vastly differed in their control of variables such as history of caffeine consumption, training history, and gender. Additionally, researchers have used a wide range of intensities for muscular endurance protocols ranging from 60-80% of one-repetition maximum. The fact that researchers have not tightly controlled for such variables may have contributed to the inconsistent results that have been seen (Goldstein et al., 2010). Finally, most studies to date have focused on males or a combination of genders, while very few studies have focused solely on females. Therefore, the purpose of this study was to determine the effects of acute caffeine ingestion on muscular endurance and perception of pain and effort in resistance trained women.

Definition of Terms

Aerobic Activity- Activities that require oxygen. (Baechle, & Earle, 2000)

Anaerobic Activity- Activities that do not require the presence of oxygen. (Baechle, & Earle, 2000)

Muscular Endurance- A training regimen that involves performing many repetitions, 12 or more, per set. (Baechle, & Earle, 2000)

One-Repetition Maximum- The greatest amount of weight that can be lifted with proper technique for only one repetition. (Baechle, & Earle, 2000)

Power Lifting- A competitive sport involving a maximal attempt of three lifts: squat, bench press, and deadlift.

Repetition- The number of times an exercise can be performed in one set. (Baechle, & Earle, 2000)

Resistance Training- The movement of your limbs against resistance provided by your body weight, resistance bands, dumbbells, and barbells. (Scott, 2017)

Rest Period- Time dedicated to recovering between sets and exercises. (Baechle, & Earle, 2000)

Set- A group of repetitions sequentially performed before the individual stops to rest. (Baechle, & Earle, 2000)

CHAPTER II

REVIEW OF LITERATURE

The following chapter will review the current literature that exists on caffeine and its relationship to exercise performance. This chapter will discuss the background and physiological effects of caffeine and how it affects exercise performance. Additionally, the effect on caffeine perceptual responses to exercise will be discussed.

Caffeine

Caffeine is a central nervous stimulant that is heavily used, with 90% of U.S adults consuming it on a daily basis (Astorino & Roberson, 2010). On average, adults consume around 200 mg of caffeine per day (two 5-ounce cups of coffee or four sodas). It is a popular substance among individuals due to its stimulant properties on the central nervous system which can enhance one's alertness, attention, and cognitive performance (Elmenhorst, Meyer, Matusch, Winz, & Bauer, 2012). There are physiological mechanisms that have been proposed to explain the effects previously stated. One consistent finding is that caffeine acts as an antagonist on adenosine receptors, which in turn leads to enhanced alertness and heightened cognitive performance (da Silva et al., 2015). There are numerous factors that can impact caffeine metabolism. Cigarette smoking has been shown to effect caffeine metabolism by accelerating demethylation , which can have an effect on the rate of caffeine clearance from the body (Parson & Neims, 1978). Effects of caffeine on woman have been studied in relation to their menstrual cycle, interactions with oral contraceptives, pregnancy, and postmenopausal health. Earlier studies have shown that caffeine clearance can vary across a women's menstrual cycle, being around 25% longer in the luteal phase (Balogh, Irmisch, Klinger, Splinter, & Hoffman, 1987). Kamimori et al. (1999) did not observe any significant effect of caffeine metabolism in relation to phases of the menstrual cycle, so data on this topic is inconsistent. It is also known that the use of oral contraceptives can increase caffeine half-life (Abernethy & Todd, 1985). There are numerous factors that can contribute to the variability in how caffeine is metabolized in individuals, especially females.

Caffeine Administration

Caffeine is rapidly and entirely absorbed from the gastrointestinal tract into the bloodstream following ingestion (Eteng, Eyong, Akpanyung, Agiang, & Aremu, 1997). There are numerous factors that affect the rate of absorption such as dosage and dose formulation, but caffeine is typically completely absorbed one hour following ingestion. (Bell & McLellan, 2002). It is typical for researchers to administer caffeine via capsule or liquid form one hour prior to performance to ensure the caffeine has reaches peak plasma concentrations during exercise.

As previously stated, researchers typically administer caffeine in a capsule or liquid formulation, but recently, studies have been utilizing caffeine gum. The gum formulations offer several advantages over capsule or liquid formulations; one being it is absorbed at a faster rate. A gum formulation for caffeine, Military Energy gum (MEG), previously known as Stay Alert gum, has been developed. It was originally implemented in studies to examine effective use during military operations. In preliminary testing by Novum Inc. in 1998, the absorption rate of caffeine was faster when it was administered in chewing gum as compared with a standard capsule. Ryan et al. (2012) studied the most effective time to administer MEG to enhance cycling performance. The gum was administered 120, 60, and five minutes prior to performance. Overall, there were no differences in plasma concentrations in the three trials before or after performance. However, peak plasma concentration continued to elevate throughout the trial when it was administered five minutes prior to performance, while concentrations remained stable in 120 and 60 minute groups. The major finding of this study was that cycling performance was greatest when the caffeine gum was administered five minutes prior to cycling performance. Another study done by Kamimori et al. (2002) studied the difference between absorption rate and time to peak concentration in MEG and a capsule formulation. Researchers found that the rate of drug absorption from MEG was significantly faster compared to the capsule formulation. Researchers also found that only 85% of the caffeine is released from the gum following the first five minutes of ingestion (Novum, 1998). Syed, Kamimori, Kelly, and Eddington (2005) studied the effects of multiple doses of MEG on peak concentrations to determine the most effective dosing regimen on individuals in military operations. Researchers found that administering multiple doses of MEG provides an effective and convenient way to help maintain alertness in individuals. The onset of action for the gum delivery is within 5 to 10 minutes of administration. Another dose can be immediately administered if a higher dose is needed. In contrast, the initial dose in a capsule or liquid formulation would require between 30 to 45 min before a decision can be made if more is needed. Therefore, administering MEG gum may provide a more convenient, fast, and effective way of ingesting caffeine compared to liquid or capsule formulation.

Stimulants and Exercise

Stimulants activate the central nervous system to improve mental aptitude and physical function (Angell et al., 2012). Common stimulants used by individuals are caffeine, nicotine, and ephedrine. They are perceived to be ergogenic as they have been shown to enhance exercise performance in a variety of ways. There has been controversy surrounding the use of these aids during exercise and sports performance, as a number of them are illegal and have detrimental side effects, most notably places significant side effects (Avois et al., 2006). The increased use of various stimulants during sports and exercise performance has raised a number of ethical and health concerns.

Caffeine and Exercise

As previously stated, caffeine is the most widely used stimulant, with 90% of U.S adults consuming it every day (Astorino & Roberson, 2010). With the multitude of dangerous and illegal stimulants, caffeine is a legal and socially acceptable substance that is used by many athletes to enhance their exercise performance (Graham, 2001). The ergogenic benefits of caffeine have been extensively studied. Research has indicated that low-to-moderate doses of 3-9 mg/kg of body weight can show a positive effect on exercise performance (Graham & Spriet, 1996). Other studies have found that doses higher than 6 mg/kg of body weight do not further enhance performance, and potentially cause negative side effects such as jitteriness, increased heart rate, and anxiety (Ganio, Klau, Casa, Armstrong, & Maresh, 2009). There are several proposed mechanisms of action that could explain caffeine's role in improving exercise performance. Previously, the proposed mechanism was believed to be the increased availability of free fatty acids and fat oxidation. This produces greater fat metabolism in the muscle and inhibits carbohydrate metabolism, leading to glycogen sparing and prolonging time to fatigue (Costill, Dalsky, & Fink, 1978). This mechanism has received mixed reviews, as this mechanism might explain its effect on aerobic exercise, but not anaerobic (Green et al., 2007). Jackman, Wendling, Friars, and Graham (1996) conducted a study examining metabolic, catecholamine, and endurance responses as a result of caffeine ingestion during intense exercise. Major findings included a significant increase in endurance time between caffeine and a placebo, while there was no significant difference in muscle glycogen between the two trials, thus discrediting the proposed mechanism's impact on anaerobic exercise performance. Recent research has suggested that the significant physiological mechanism of caffeine on performance is its effect on the central nervous system competing with adenosine at its receptor sites. This reaction causes numerous physical, emotional, and mental changes that help improve performance. These changes include increased focus, alertness, arousal, and blunted pain perception (Goldstein et al., 2010).

There is broad research that has been done on the effects of caffeine in relation to exercise performance. Studies continue to emerge that expand and add to the current literature regarding the physiological effects. Some studies show conflicting results that only pose more questions regarding the duration, intensity of exercise and population that is affected the most by caffeine. Goldstein et al. (2010) stated that the differences in results of these studies could be the variety of intensities used within the exercise protocols and level of habitual caffeine consumption by subjects. A meta-analysis by Doherty and Smith (2004) examined the effect of caffeine on endurance exercise during time to exhaustion, and on short-term, high-intensity exercise protocols. It was shown that caffeine ingestion showed a greater improvement in endurance time to exhaustion compared to short-term, high-intensity performance. The positive effects that caffeine poses on endurance performance are well documented. Costill et al. (1978) performed a study on the effects of caffeine ingestion on endurance performance. Nine men and women exercised on a cycle ergometer to exhaustion at 80% of maximal oxygen uptake. Time to fatigue was 20% greater after ingesting 330 mg of caffeine compared to placebo. Bell and McLellan (2002) tested the effects of 5 mg/kg of caffeine on performance at 80% maximal oxygen consumption 1, 3, or 6 hours after ingesting caffeine. Participants showed significant improvement in their exercise time after ingesting caffeine and performing 1 or 3 hours later.

Studies show a strong improvement in endurance performance, but its impact on higher intensity exercise is less clear. One study was done to test the impact of caffeine ingestion on aerobic endurance and anaerobic power. Physically active, college aged individuals performed two 30-second Wingate anaerobic tests, and two cycle ergometer tests performing at 75% of their Vo2 max to fatigue. Comparing their performances after ingesting coffee or decaffeinated coffee, the subject's performance showed no differences anaerobic power, but showed a significant increase in time to exhaustion during the aerobic tests (Hoffman, et al., 2007). Research firmly supports the positive effect of caffeine on endurance exercise, yet few studies have examined the effects of caffeine on short, higher intensity performance. More research needs to be done on this topic (Astorino & Roberson, 2010).

Caffeine and Resistance Exercise

Resistance training has long been accepted in enhancing muscular endurance, strength, power, and muscle mass. It plays a vital role in overall health and fitness and to aid in improving activities of daily living (Pollock et al., 2000). The American College of Sports Medicine's position stand on resistance training include the use of concentric, eccentric, and isometric muscle actions and the performance of single-joint and multiple-joint exercises. The American College of Sports Medicine added guidelines for resistance training in 1990. These guidelines have been widely implemented in exercise programs for individuals ranging from children, to adolescents, to older adults (ACSM, 2009). The effectiveness of caffeine as an ergogenic aid during aerobic endurance training is well known and extensively researched, but its effects on resistance training are less clear, as studies done on this topic are inconsistent (Astorino, Martin, Schachtsiek, Wong, & Ng, 2011). A review of literature done by Astorino & Roberson (2010) assessed the research that exists on caffeine and resistance exercise. Six of 11 studies suggested that there are significant benefits of caffeine on resistance training; while some studies showed negative effects on performance with caffeine ingestion when repeated bouts were completed. Due to the popularity of resistance training and widespread use of caffeine as an ergogenic aid, additional research is needed.

Andre, Green, Gann, O'Neal, and Coates (2015) studied the impact of caffeine ingestion on anaerobic power by testing anaerobically trained males on an upper and lower body Wingate test. There was no significant impact observed, and the researchers suggested this topic needs to be studied further. Researchers also suggested that perceptual responses to exercise should be additionally tested. Beck at el. (2006) performed a study testing muscular strength, endurance, and anaerobic power during upper and lower body exercises. The results were also inconsistent, showing only an improvement in upper body strength. The results showed no improvement in lower body strength, upper and lower body muscular endurance, and anaerobic power. Researchers of this study suggested that confounding variables, such as dosages of caffeine had an impact on the results. Astorino, Rohmann, and Firth (2008) tested the effects of caffeine on muscular strength and muscular endurance. Twenty-two resistance trained men ingested 6 mg/kg of caffeine or a placebo. They performed a one-repetition maximum test and performed repetitions to failure at 60% of their 1-RM. RPE were determined after each failed repetition. There were no significant differences in muscular strength with caffeine compared to the placebo. Total weight lifted during the muscular endurance protocol resulted in an 11-12% increase in both exercises due to the ingestion of caffeine, but was nonsignificant due to the non-homogeneous sample of subjects. Additionally, there was no significant difference in RPE between caffeine and placebo ingestion. Researchers also believed the lack of significance demonstrated was due to their lack of controlled variables such as subject's caffeine consumption and training history. Authors suggested future studies should focus on controlling these variables to ensure consistent results. Literature on the effect of caffeine in muscular strength is apparently less clear compared to muscular endurance and anaerobic power. It has been shown that caffeine can have an ergogenic effect on muscular strength and muscular endurance, but more research needs to be done (Warren et al., 2010).

There are numerous proposed physiological mechanisms that could explain the impact of caffeine upon muscular endurance and strength. As previously stated, its actions on the central nervous system are believed to cause arousal, alertness, and blunt pain perception and fatigue. This would explain one's ability to enhance muscular endurance and feeling less perception of effort during the activity (Richardson & Clarke, 2016). Through the antagonism of the adenosine receptors, motor unit recruitment could be altered and an enhanced excitation-contraction coupling could occur to explain the effects of caffeine on muscular strength (Astorino, Rohhmann, &Firth, 2008). In essence, the inconsistencies in these studies pose more questions that need to address if and how caffeine affects resistance training performance.

Caffeine and Muscular Endurance

Muscular endurance is the ability to exert force against resistance repeatedly (Hass, Feigenbaum, & Franklin, 2001). The American College of Sports Medicine's guidelines for targeting muscular endurance are performing greater than 15 repetitions at 40-60% of an individual's one-repetition maximum. As previously stated, the effects of caffeine on muscular endurance training are less clear compared to aerobic endurance training. The majority of studies done to determine the effect of caffeine on muscular endurance have focused on the number of repetitions subjects can perform until failure. There are numerous studies that show positive effects of caffeine on muscular endurance (da Silva et al., 2015). Duncan and Oxford (2011) reported an increase in repetitions to failure at 60% of subject's one-repetition maximum in bench press after ingesting 5 mg/kg of caffeine in moderately trained men Subjects of this study also reported a lower RPE during the activity. Hudson, Green, Bishop, and Richardson (2008) also reported a positive effect of caffeine using the subject's 12 repetition maximum with 6 mg/kg of caffeine. Conversely, there are studies that have reported no effect of caffeine on muscular endurance. Goldstein et al. (2010) reported no effect of 6 mg/kg of caffeine on performance at 60% of one-repetition maximum on bench press. Essentially, further research is needed on this topic in order to clarify the issue. The control of variables in studies such as history of caffeine intake, training history, gender, and exercise protocols have differed from one study to the next (Goldstein et al., 2010). It is imperative that future studies on this topic have greater control on confounding variables. Furthermore, another issue that requires more clarity us the impact of caffeine ingestion upon an individual's perception or exertion during muscular endurance related activities. A mechanism that could potentially explain the ergogenic effect of caffeine on muscular endurance is subject's perceptual responses to exercise (da Silva et al., 2015). RPE Scales have been heavily used during these studies, where a 5.6% decrease in RPE has been shown following the ingestion of caffeine of studies (Doherty & Smith, 2005).

Caffeine and Ratings of Perceived Exertion

Considering the numerous proposed mechanisms of action that caffeine has on exercise performance, one consistent finding is that caffeine alters an individual's perception of effort during activity regardless of mode, intensity, or duration (Doherty & Smith, 2005). This leads to the assumption that part of the positive effects of caffeine ingestion on resistance training is due to the reduction of perceived effort and pain perception during the activity, this in turn allows an to perform more repetitions to fatigue (da Silva et al., 2015). In previous studies, too much focus has been put solely on performance, but it is important to take perceptual responses into consideration to truly understand all aspects of performance (Borg, 1990). The scale that is widely used to rate individual's perceived exertion is the Borg Rating of Perceived Exertion Scale (RPE). It is scaled from 6-20, with the numerals intending to correspond to how hard the individual feels the task is (Borg, 1990). It quantifies an individual's perception of exertion during exercise in order to determine or control the exercise intensity that correlates with the percentage of maximal heart rate (Silva et al., 2014). Morishita Yamauchi, Fujisawa, and Domen (2013) explained that this scale is widely used and catered to patients with cardiovascular disease and metabolic disease such as hypertension and Type II Diabetes. Professionals are unsure how to modify this scale to properly determine the exercise intensity in resistance exercise. The OMNI Resistance Exercise Scale (OMNI scale) was developed as an alternative for Borg's RPE scale (Robertson et al., 2003). This scale is implemented at the end of a resistance exercise to quantify how hard they feel their muscles are working. Many studies have reported the OMNI scale to be an accurate and reliable tool for selecting the appropriate intensity of resistance exercise to improve muscular fitness (Naciero, Rodriguez-Romo, Barriopedro-Moro, Jimenez, & Alvar, 2011). Lagally and Robertson (2006) reported that this scale exhibits high construct validity, indicating that it measures the same properties of the Borg RPE scale. These researchers indicated that the OMNI scale can be used in place of the Borg RPE scale.

Several studies done on this topic have showed that caffeine intake before exercise raises lactate levels while concurrently lowering RPE (Graham, 2011). Overall, research suggests that caffeine modifies perceptual responses such as RPE, but further research is needed to test these responses in different populations and modes of exercise (Astorino, Cottrell, Talhami, Aburto, & Duhon, 2012). Backhouse et al. (2011) observed a significant decrease in RPE during steady-state cycling to exhaustion following the ingestion of caffeine. Graham et al. (1998) also revealed a significant impact of caffeine on RPE compared to placebo in steady-state running to voluntary exhaustion. Demura, Yamada, and Terasawa (2007) observed a significant difference in RPE during submaximal endurance cycling. The majority of studies typically observe RPE during steady-state exercise, while few test RPE on higher intensity activities such as resistance exercise, in which results are less consistent (Astorino & Roberson, 2010). Accounting for RPE during resistance exercise could potentially explain enhanced performance, as individuals have the ability to perform more repetitions to fatigue due to perceiving less effort (Green et al., 2007). Smith et al. (2012) studied the acute effects of caffeine on repetitions to failure and RPE during the performance of four resistance exercises. Researchers found that subjects were able to perform a greater total volume while reporting a lower RPE during the activity. Researchers of this study suggested that any inconsistent results in the past on this topic were due to the short duration of the exercises being performed. Duncan et al. (2011) also observed a significant effect of caffeine on RPE during repetitions to failure during resistance exercise, reporting RPE was significantly lower following the ingestion of caffeine. A study done by da Silva et al. (2015) found that caffeine increased the number of repetitions to failure in resistance trained men, while RPE remained the same across conditions. Researchers of this study stated that although RPE remained the same, subjects were able to perform more repetitions while perceiving similar effort, therefore suggesting that the positive effect of caffeine is credited to a reduced RPE. Green et al. (2007) had similar findings, subjects performed more repetitions to fatigue after ingesting caffeine while RPE remained the same across conditions. Further studies need to investigate the interaction of caffeine, RPE, and performance together with possible mediators such as mood, pain, and cardiorespiratory dynamics (Doherty & Smith, 2005).

Caffeine and Pain Perception

Acute exercise is a natural stimulus that can briefly, safely, and reliably produce pain (Cook, Jackson, O'Connor, & Dishman, 2004). Moderate-to-high-intensity exercise typically results in pain that is described as exhausting, intense, sharp, burning, cramping, pulling, and rasping (Cook, O'Connor, Oliver, & Lee,1998). Similar to rating of perceived exertion, caffeine seems to have an effect on an individual's perception of pain during exercise. Several studies done on this topic have resulted in subject's improved performance and lower perception of effort and pain following the ingestion of caffeine; even though individual's had higher lactate levels at the conclusion of the activity (Hudson et al., 2008). Researchers believe the positive effects of caffeine on resistance training is owed to the reduction of pain perception and perceived exertion during exercise (Duncan, Stanley, Parkhouse, Cook, & Smith, 2011). This is important because perceiving less pain and effort during exercise can result in enhanced performance (Astorino, Terzi, Roberson, & Burnett, 2010).

Recent evidence has highlighted the role of caffeine in attenuating naturally occurring muscle pain during exercise (Motl et al., 2006). Motl et al. (2003) revealed significant reductions in leg muscle pain when 10 mg/kg was administered to subjects who performed 30 minutes of cycling at a moderate intensity. O'Connor, Motl, Broglio, & Ely (2004) administered only 5 mg/kg of caffeine to men performing for 30 minutes on the cycle ergometer, a reduction in pain perception during the activity was also found. Collectively, data continues to demonstrate caffeine-induced attenuations in pain during exercise regardless of the dosage administered (Asrorino et al., 2010). Whether or not the impact of caffeine ingestion varies depending on the mode of exercise is unclear. Studies have examined the efficacy of caffeine to reduce muscle pain during and after aerobic exercise (Motl, O'Connor & Dishman, 2003), and at high intensity exercise at 80% Vo2 Maximum (Gliottoni & Motl, 2008). However, it is less clear whether or not pain perception is reduced during resistance exercise, where repeated, near maximal to maximal efforts occur and are more likely to induce pain compared to aerobic exercise. Astorino et al. (2011) examined the effects on 5 mg/kg of caffeine ingestion on pain perception when an all out bout of 40 repetitions of resistance exercises was performed. There was no difference in pain perception between the caffeine and placebo group, and subject's performance greatly improved following the ingestion of caffeine. This suggests that caffeine blunts pain when individuals perform more repetitions following caffeine ingestion while reporting no difference in pain. Duncan et al. (2011) evaluated the effects on 5 mg/kg of caffeine ingestion on repeated sets to failure while performing four different resistance exercises. There was a significant increase in repetitions to failure with the ingestion of caffeine compared to the placebo group, and a significant reduction in pain perception as well. This study added to the literature by including upper body as lower body exercises in a protocol, instead of using one or two exercises where perception or performance may not produce a significant effect with the short nature in duration of exercise. Astorino et al. (2011) reported no significant changes in leg pain perception following repeated bouts of isokinetic knee extension and flexion following caffeine ingestion. If attenuated pain perception following caffeine ingestion is associated with improved performance in the presence of caffeine, using a greater number of exercises may be needed in order for changes in pain perception to become apparent (Duncan et al., 2011).

CHAPTER III

METHODS

Purpose

The purpose of the present study was to determine the effects of acute caffeine ingestion on muscular endurance performance and perceptions of pain and effort in resistance trained women.

Participants

Eleven females from the Indiana University of Pennsylvania (IUP), 19-25 years of age participated in this study double-blind, repeated measures within subjects study with. Participants met the inclusion criteria if they resistance trained for at least 2 months, 2-4 days per week, ingested no more than 300 mg of caffeine (3 cups of coffee) on an average daily basis, weighed between 110-220 lbs, were free of high blood pressure or musculoskeletal injuries, were not currently taking any anxiety medication, pain medication/killers, and/or blood pressure medication, and were not pregnant nor taking oral contraceptives. Additionally, participants were excluded if they competed in weightlifting competitions. Participants were recruited via word of mouth, visitations to classrooms in the Kinesiology, Health and Sports Science Department, and flyers posted in dining halls and residence buildings at IUP (Appendix A). During initial contact with potential participants, the principal investigator explained the purpose of the study and criteria that needed to be met in order to participate. They were also provided contact information of the principal investigator if they showed interest in participating. When females contacted the principal investigator, they were provided a further detailed explanation and requirements of the study. The principal investigator went through a verbal checklist regarding information on eligibility such as caffeine consumption, resistance training history, musculoskeletal injuries etc (Appendix C). Individuals who verbally ensured they met the inclusion criteria were asked to meet for a pre-assessment session. Potential participants were notified they were to report for a total of three sessions, for one hour each session. They understood they would be exercising for all three sessions.

Procedures

Session 1(Orientation/Pre-Assessment)

Orientation. Orientation took place in the James G. Mill Fitness Center in Zink Hall. The principal investigator provided a more detailed explanation of what to expect during the exercise sessions. Participants signed the consent form (Appendix D) following the explanation of the study and filled out a demographics questionnaire (Appendix E) further ensuring they fit the inclusion criteria. Participants were randomly assigned to the experimental conditions, caffeinated gum or placebo gum. The OMNI RPE Scale (Appendix L) and Pain Perception Scale (Appendix M) were explained in detail and participants were provided visuals of the scales. Participants were then provided a list of foods, drinks, and any other caffeinated products to abstain from at least 48 hours prior to each exercise session (Appendix F). Additionally, they received instruction to abstain from any pain medication, alcohol, and vigorous activity the day before each exercise session. Participants were also advised to have a similar dietary intake the day before both exercise sessions.

Pre-assessment. Pre-assessment consisted of baseline measures being taken and determination of one-repetition maximum (1-RM) of the leg extension and chest press. Weight was determined using a physician's scale (Appendix H) to ensure participants met the weight criteria along with baseline heart rate and blood pressure using a Polar Heart Rate Monitor (Appendix I) and blood pressure cuff (Appendix K). Secondly, participants performed a five minute warm up on a Precor treadmill (Appendix O) for five minutes at three miles per hour.

Before beginning the 1-RM protocol, participants were instructed on proper form on the leg extension (Appendix P) and chest press (Appendix Q). Once participants were acquainted with both exercises, the principal investigator ran participants through the 1-RM protocol (Appendix G) for the chest press and leg extension. Following determination of participant's 1-RM, 60% of their one-repetition maximum was calculated for each exercise based upon National Strength and Conditioning Association guidelines (NSCA, 2000). This was the designated weight to be lifted during exercise sessions I and II. After completion of the 1-RM of the leg extension and chest press, participants were familiarized with the protocol to be used during the exercise sessions yet to be completed. Participants completed one set of each exercise until failure utilizing 60% of their 1-RM for each exercise. This ensured participants were familiar with what exercising to exhaustion felt like, how to perform to the beat of a metronome (Appendix N), and how to properly rate perceptions of exertion and pain. Once the pre-assessment was completed, participants performed cool down stretches of their choice. Each stretch was held for 10-30 seconds based on ACSM's guidelines for stretching (ACSM, 2009).

Exercise Sessions I and II

Exercise sessions I and II occurred two weeks following participant's final day of their menstrual cycle and were at least 48 hours apart to ensure the phase of the menstrual cycle was not a confounding factor on performance. The protocols followed during each exercise session were identical, with the only difference being the condition (caffeine or placebo). Upon arrival in the Zink Hall Human Performance lab, resting heart rate and blood pressure were taken. Participants wore the heart rate monitor for the duration of the protocols.

Caffeine administration. Following determination of resting heart rate and blood pressure, participants received two pieces of Military Energy Gum (MEG) (200 mg), or placebo gum. Each piece of caffeinated gum contained 100 mg of caffeine. Placebo gum was provided by the same manufacturer as the caffeinated gum, provided in the same packaging and had the same appearance and taste as the caffeinated gum. It was unknown to the participant and principal investigator which one they were ingesting. A co-investigator held the information regarding the random assignment of conditions until data collection was complete. Participants rested in Zink Hall Human Performance Laboratory. After 10 minutes of rest, participants disposed the two pieces of gum and ingested one more piece of MEG (100mg) or placebo. Therefore, participants ingested a total of 300 mg of caffeine, during the caffeine condition. Participants rested for another five minutes while chewing the gum. Following this duration, participants disposed of the gum, and heart rate and blood pressure were taken.

Muscular endurance protocol. Participants were taken to the James G. Mill Fitness Center to complete the exercise protocols. A five minute warm up was completed on a Precor treadmill at 3.0 mph. Following the warm-up, participants completed three sets of repetitions until failure on the leg extension and then the chest press machine. The weight lifted during the exercise protocols represented 60% of participant's 1-RM for each exercise previously determined during the pre-assessment session. The principle investigator held the pain perception and OMNI RPE scale in front of participants to rate immediately following the final repetition of each set of each exercise. Heart rate and blood pressure were also taken during a three minute rest period between each set of each exercise. A five minute rest period occurred between exercises. Repetitions were performed to the beat of a metronome at 60 beats per minute using Metronome App™. Each repetition consisted of a two second concentric movement and two second eccentric movement. Repetitions, pain perception, OMNI RPE, heart rate, and blood pressure were collected with the assistance of a student intern. Once both exercises were completed, participants went through a cool down by performing upper body and lower body stretches of their choice for five minutes. This concluded the exercise sessions. Prior to the second session, the principal investigator reiterated the importance of abstaining from caffeine, pain medications, and vigorous activity prior to the next session. The second exercise session was identical to the first, with the exception of the condition (caffeine or placebo).

Statistical Analyses

The following chapter will describe the statistical analyses utilized to describe the results found in this study. The study design is a double-blind, quasi experimental design with repeated measures. Participants repeated the exercise protocol entailing the same procedures twice under two different conditions (caffeine consumption and placebo) in a randomized manner. All data was assessed for normality. Normal data will be presented as mean and standard deviation; non-normal data as median and interquartile range. Descriptive characteristics were used to describe the study population. A two-way analysis of variance was used to compare the impact of study condition on outcome variables such as repetitions to failure and RPE, repeated measures. A one-way analysis of variance was used to compare means of variables within conditions. Post Hoc analysis was run to determine the main effect of time.

CHAPTER IV

RESULTS

The research question for the present study is stated as follows: what are the effects of acute caffeine ingestion on muscular endurance and perception of pain and effort in resistance trained women? The following chapter will present statistical analyses performed on data from the 11 participants that completed the study.

Demographics

Of the 12 females that were recruited for the study, eleven females completed the pre-assessment and two exercise sessions. One participant was excluded from participating in the study because her one-repetition maximum exceeded the total amount of weight on the leg extension machine. All participants completed the exercise sessions under two conditions (caffeine and placebo) in a randomized manner. All 11 females were currently enrolled students from the Indiana University of Pennsylvania. Table 1 presents demographic characteristics of these 11 participants.

Table 1

Demographic Characteristics of Participants

	Mean (±SD)
Age (years)	21.45 ± 1.69
Weight (kg)	67.86 ± 24.80
Resting Heart Rate (beats per minute)	79.18 ± 12.0
Resting Systolic Blood Pressure (mmHg)	105.8 ± 6.70
Resting Diastolic Blood Pressure (mmHg)	69.1 ± 8.41

Table 2 displays participant descriptive characteristics presented as mean (+ standard deviation), median, interquartile range, and upper and lower bound values regarding resistance training history, caffeine consumption, resistance training history, one-repetition maximum, and weight lifted during exercise sessions (60% 1-RM).

Table 2

Descriptive Characteristics of Participant's Training History, Caffeine Consumption, and Weight Lifted During Protocols

	Mean + SD	Median(IQR)	Minimum	Maximum
Average caffeine consumption per day (mg)	209.18 + 108.71	180.5 (217.5)	68.0	390.0
Days per week of caffeine consumed	5.2 + 1.5	5.0 (3.5)	3.0	7.0
Duration of Resistance Training (mo)	24.0 + 24.52	18.0 (57)	2.0	60.0
Days per week of resistance training	3.2 + 0.65	3.0 (1)	2.5	4.5
Leg Extension 1-RM (lbs)	225 + 35.5	220.0 (65)	185.0	295.0
Chest Press 1-RM (lbs)	155.45 + 24.45	165.0 (45)	120.0	190.0
60% Leg Extension 1-RM (lbs)	134.1 + 21.3	130.0 (40)	110.0	175.0
60% Chest Press 1-RM (lbs)	90.9 + 15.1	90.0 (15)	70.0	115.0

The following sections will present results for the three hypotheses of the present study. Initially, a one-way analysis of variance (ANOVA) was conducted for each of the variables of interest (repetitions until failure, RPE, and pain perception) to determine if any statistically significant differences were present within the condition separately. The results of these analyses are presented in table 3. Based on the statistically significant findings, a two-way repeated measures analysis of variance (ANOVA) was performed to further compare repetitions until failure, RPE and pain perception over time while performing three sets of the leg extension and chest press between conditions.

Table 3

Results from One-Way ANOVA for Each of the Variables of Interest

Variable of Interest	F statistic	p-value
Repetitions		
Leg Extension – Caffeine	7.11	0.005
Leg Extension – Placebo	2.12	0.148
Chest Press – Caffeine	28.65	<0.001
Chest Press – Placebo	6.37	0.007
RPE		
Leg Extension – Caffeine	14.40	<0.001
Leg Extension – Placebo	2.61	0.128
Chest Press – Caffeine	9.19	0.001
Chest Press – Placebo	9.27	0.001
Pain Perception		
Leg Extension – Caffeine	9.44	0.001
Leg Extension – Placebo	6.74	0.006
Chest Press – Caffeine	10.38	0.001
Chest Press – Placebo	9.25	0.001

Effects of Caffeine Upon Variables

Hypothesis #1 states that participants would perform more repetitions prior to reaching muscular fatigue after ingesting caffeine compared to the placebo. No statistically significant differences were revealed between the mean number of repetitions performed between caffeine and placebo during the three sets of the leg extension, therefore we reject this hypothesis.

Table 4 displays means and standard deviations of repetitions performed for each set of the leg extension exercise following caffeine and placebo ingestion. During the leg extension exercise, a mean of 11.52 ± 0.72 repetitions were performed following caffeine ingestion, while a mean of 11.24 ± 0.71 repetitions were performed following the ingestion of placebo.

Table 4

Group Means and Standard Deviations of Repetitions During Three Sets of the Leg Extension

Set	Caffeine		Placebo	
	Mean	SD	Mean	SD
Set 1	12.73	2.97	11.73	2.24
Set 2	11.27	2.61	11.09	2.95
Set 3	10.55*	2.25	10.91	2.21

*Pairwise comparisons statistically different from set 1 ($p<0.05$; Bonferroni)

Table 5 displays the results of a two-way ANOVA performed to examine repetitions during three sets of the leg extension. No statistically significant condition by time interaction ($F=1.98$, $p=0.16$) or main effect of condition ($F=0.14$, $p=0.53$) was observed. However, a significant main effect of time was noted ($F=8.32$, $p=0.002$). Post hoc pairwise comparisons with Bonferroni corrections (see table 4) were also conducted to examine whether any differences existed between the numbers of repetitions performed over time (set 1 to set 3). A statistically significant difference between mean repetitions in set 1 and set 3 for caffeine was noted (*p*=0.02). No other statistically significant differences were noted for either caffeine or placebo.

Table 5

Two-Way ANOVA Summary Table of Repetitions Performed During Three Sets of the Leg Extension

Source	*Df*	Mean Square	F	Sig
Condition	1	0.14	0.42	0.53
Error (condition)	10	13.54		
Time	2	112.55	8.32	0.002
Error (time)	20	5.88		
Condition X time	2	7.82	1.98	0.16

No statistically significant differences were found between repetitions performed on the chest press exercise between caffeine and placebo. Therefore, we reject the hypothesis. Table 6 displays group means and standard deviations of repetitions performed during three sets of the chest press exercise following caffeine and placebo ingestion. During three sets of chest press, participants performed a mean of 14.64 ± 1.10 repetitions following caffeine ingestion, while a mean of 14.73 ± 1.10 repetitions were performed following placebo.

Table 6

Group Means and Standard Deviations of Repetitions Performed During Three Sets of the Chest Press

Set	Caffeine		Placebo	
	Mean	SD	Mean	SD
Set 1	17.64	3.70	16.64	4.45
Set 2	14.27*	3.72	14.18	3.52
Set 3	12.00*#	4.22	13.36	4.20

*Pairwise comparisons statistically different from set 1 (p<0.05; Bonferroni)

#Pairwise comparisons statistically different from set 2 (p<0.05; Bonferroni)

Table 7 displays a summary of two-way ANOVA results of repetitions performed during three sets of the chest press. No statistically significant condition by time interaction (F=3.53, p=0.06) or main effect of condition (F=0.01, p=0.92) was observed. However, a significant main effect of time was noted (F=19.14, p=0.001). Post hoc pairwise comparisons with Bonferroni corrections (see table 3) were also conducted to examine whether any differences existed between the number of repetitions performed over time (set 1 to set 3).

A statistically significant difference between mean repetitions was noted from set 1 and set 2 (p= 0.004), set 1 to set 3 (p<0.001), and set 2 to set 3 (p=0.003). No statistically significant main effect of time was noted for placebo.

Table 7

Two-Way ANOVA Summary Table of Repetitions Performed During Three Sets of the Chest Press

Source	*Df*	Mean Square	F	Sig
Condition	1	1.23	0.01	0.92
Error (condition)	10	2.89		
Time	2	15.24	19.14	0.001
Error (time)	20	10.74		
Condition X time	2	9.02	3.53	0.06

Hypothesis #2 states participants would rate a lower rating of perceived exertion during performance of repetitions to failure after ingesting caffeine compared to the placebo. No statistical significant differences in RPE were found between conditions during the leg extension Therefore, we reject this hypothesis.

Table 8 displays group means and standard deviations of RPE for each set of the leg extension following caffeine and placebo ingestion. During three sets of the leg extension, participants reported a mean RPE of 7.27 $\pm$ 0.29 following caffeine ingestion, and a mean RPE of 7.94 $\pm$ 0.29 following placebo.

Table 8

Group Means and Standard Deviations of RPE During Three Sets of the Leg Extension

Set	Caffeine		Placebo	
	Mean	SD	Mean	SD
Set 1	7.09	1.22	7.27	1.27
Set 2	7.91*	1.04	8.18	1.17
Set 3	8.18*	.87	8.36	1.21

*Pairwise comparisons statistically different from set 1 ($p<0.05$; Bonferroni)

Table 9 displays the two-way ANOVA summary of RPE during three sets of the leg extension. No statistically significant condition by time interaction ($F=0.03$, $p=0.97$) or maineffect of condition ($F=0.49$, $p=0.50$) was observed. However, a significant main effect of time was noted ($F=14.94$, $p<0.001$). Post hoc pairwise comparisons with Bonferroni corrections (see table 8) were also conducted to examine whether differences existed between RPE over time (set 1 to set 3). A statistically significant difference between mean RPE in set 1 and set 2 for caffeine was noted ($p=0.003$) and set 1 to set 3 ($p=0.001$).

Table 9

Two-Way ANOVA Summary Table of RPE During Three Sets of the Leg Extension

Source	*Df*	Mean Square	F	Sig
Condition	1	0.74	0.49	0.50
Error (condition)	10	1.51		
Time	2	7.28	14.94	<0.001
Error (time)	20	0.49		
Condition X time	2	0.02	0.026	0.97

There was a statistical significance found in participant's RPE during three sets of the chest press exercise. Participant's rating of RPE was significantly lower following the ingestion of caffeine compared to placebo. Therefore, we accept this hypothesis.

Table 10 displays group means and standard deviations of RPE during three sets of the chest press exercise following caffeine and placebo ingestion. During the three sets, participants reported a mean RPE of 7.24 $\pm$ 0.35 following caffeine ingestion, and a mean RPE of 7.67 $\pm$ 0.73 following placebo.

Table 10

Group Means and Standard Deviations of RPE During Three Sets of the Chest Press

Set	Caffeine		Placebo	
	Mean	SD	Mean	SD
Set 1	6.73	1.35	7.09	1.30
Set 2	7.36*	1.12	7.64	1.12
Set 3	7.64*	1.21	8.27*#	1.19

*Pairwise comparisons statistically different from set 1 (p<0.05; Bonferroni)

*# Pairwise comparisons statistically different from set 2 (p<0.05; Bonferroni)

Table 11 displays a summary of two- way ANOVA of RPE during three sets of the chest press. No statistically significant condition by time interaction *(F*=1.09, *p*=0.36*)* was observed. However, there was a significant main effect of condition *(F*=5.90, *p*=0.04*)*, and a main effect of time *(F*=12.20, *p*=<0.001*)*. Post hoc pairwise comparisons with Bonferroni corrections (see table 12) were also conducted to examine whether any differences existed between RPE over time (set 1 to set 3). A statistically significant difference between mean repetitions for caffeine was noted from set 1 to set 2 (*p*=0.03), and set 1 to set 3 (*p*=0.01). A statistically significant difference for placebo in RPE was noted from set 1 to set 3 d (p=0.01) and set 2 to set 3 (p=0.03). Figure 1 displays a visual representation of RPE during three sets of the chest press between caffeine and placebo.

Table 11

Two-Way ANOVA Summary Table for RPE During Three Sets of the Chest Press

Source	*Df*	Mean Square	F	Sig
Condition	1	2.97	5.90	0.04
Error (condition)	10	0.503		
Time	2	6.04	12.20	< 0.001
Error (time)	20	0.495		
Condition X time	2	0.20	1.09	0.36

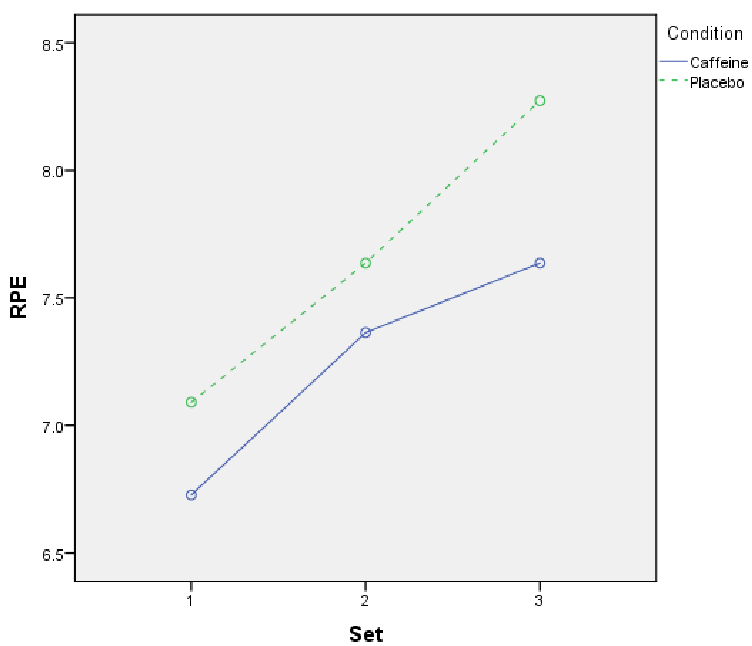

Figure 1. Mean RPE during three sets of the chest press.

Hypothesis #3 states that participants would rate a lower perception of pain during performance of repetitions until failure after ingesting caffeine compared to the placebo. No statistical significant results were found between condition and participant's perception of pain during three sets of the leg extension. Therefore, we reject this hypothesis.

Table 12 displays group means and standard deviation of pain perception during three sets of the leg extension. Participants reported a mean pain perception of 4.77 ± 0.64 following caffeine ingestion, and a mean pain perception of 5.27 ± 0.72 following placebo.

Table 12

Group Means and Standard Deviations of Pain Perception During Three Sets of the Leg Extension

Set	Caffeine		Placebo	
	Mean	SD	Mean	SD
Set 1	4.41	2.20	4.82	2.36
Set 2	4.73	2.05	5.18	2.18
Set 3	5.18*	2.28	5.82*	2.60

*Pairwise comparisons statistically different from set 1 (p<0.05; Bonferroni)

Table 13 displays a summary of two-way ANOVA of pain perception during the leg extension. No statistically significant condition by time interaction (F=2.54, p= 0.78) or main effect of condition (F=3.41, p=0.09) was observed. However, a main effect of time was noted (F=15.65, p<0.001). Post hoc pairwise comparisons with Bonferroni corrections (see table 12) were also conducted to examine whether any differences existed between the pain perception over time (set 1 to set 3). A statistically significant difference between pain perception in set 1 and set 3 for caffeine was noted (p=0.005). A statistically significant difference between pain perception in placebo from set 1 to set 3 was noted (p=0.02).

Table 13

Two-Way ANOVA Summary Table of Pain Perception During Three Sets of the Leg Extension

Source	*Df*	Mean Square	F	Sig
Condition	1	4.13	3.41	0.09
Error (condition)	10	1.21		
Time	2	4.40	15.65	<0.001
Error (time)	20	0.28		
Condition X time	2	0.08	0.25	0.78

No statistically significant differences were found in pain perception between conditions during the chest press. Therefore, we reject this hypothesis.

Table 14 displays group means and standard deviations of pain perception during three sets of the chest press. Participants rated a mean pain perception of 4.5 ± 0.77 following caffeine ingestion, and 4.62 ± 0.70 following placebo.

Table 14

Group Means and Standard Deviations of Pain Perception During Three Sets of the Chest Press

Set	Caffeine		Placebo	
	Mean	SD	Mean	SD
Set 1	3.77	2.07	3.86	1.87
Set 2	4.64	2.98	4.55	2.51
Set 3	5.00*	5.00	5.45*	2.84

*Pairwise comparisons statistically different from set 1 (p<0.05; Bonferroni)

Table 15 displays a two-way ANOVA summary of pain perception during three sets of the chest press. There was no statistically significant condition by time interaction (F=0.25, *p*=0.26*)* or main effect of condition *(F*=0.45*, p*=0.52*).* However, a significant main effect of time was found *(F*=12.34*, p*=< 0.001). Post hoc pairwise comparisons with Bonferroni corrections (see table 14) were also conducted to examine whether any differences existed between the pain perceptions over time (set 1 to set 3). A statistically significant difference between mean repetitions in set 1 and set 3 for caffeine was noted (*p*=0.006). A statistically significant difference was also found in placebo from set 1 to set 3 (*p*=0.01).

Table 15

Two-Way ANOVA Summary Table of Pain Perception During Three Sets of the Chest Press

Source	*Df*	Mean Square	F	Sig
Condition	1	0.38	0.45	0.52
Error (condition)	10	0.85		
Time	2	14.93	12.34	<0.001
Error (time)	20	0.888		
Condition X time	2	0.478	0.254	0.256

CHAPTER V

DISCUSSION, LIMITATIONS, RECOMMENDATIONS FOR FUTURE RESEARCH

Discussion

The ergogenic impact that caffeine has on exercise performance has been widely researched, (Goldstein et al., 2010). It has been established that caffeine enhances aerobic endurance performance, while the benefits of caffeine upon resistance training is less clear. The control of variables in studies such as participant's history of caffeine intake, training history, gender, and exercise protocols have differed from one study to the next (Goldstein, et al., 2010). Research studies examining the effects of caffeine on resistance training in women is also very limited, Therefore, The purpose of this study was to determine if acute caffeine ingestion has an effect on muscular endurance performance and perception of pain and effort in resistance trained women

Results of this study suggest that caffeine ingestion did not have an impact on women's performance of repetitions to failure and the rating of pain perception while performing three sets of the leg extension and chest press. Acute caffeine ingestion also did not have an effect on RPE during the leg extension exercise. However, results showed that caffeine had a significant effect on RPE during three sets of the chest press.

The first hypothesis states that caffeine would result in participants performing more repetitions to muscular fatigue on the leg extension and chest press compared to placebo. These findings contrast with those of Duncan and Oxford (2010), who found a significant increase in repetitions until failure when 13 moderately trained men performed repetitions until failure at 60% of their 1-RM following the ingestion of caffeine compared to placebo. A study done by da Silva et al. (2015) also reported a positive effect of caffeine in 14 moderately resistance trained men on repetitions until failure on the bench press and leg press. It is important to note differences from the present study to those previously mentioned, as they have used men as subjects, while the present study used women as subjects. There are few studies to compare the effects of caffeine upon women during muscular endurance performance. Results of the present study correspond to research done by Goldstein et al. (2010) that did not find any significant impact of caffeine ingestion on repetitions until failure in resistance trained women. These findings suggest there may be differences in how caffeine affects men and women in relation to resistance exercise performance. The majority of research done on this topic primarily utilizes men subjects, while research on this topic on women is limited. The lack of significance in repetitions until failure following the ingestion of caffeine in resistance trained women suggests that caffeine does not affect women's muscular endurance performance. One potential factor that may contribute to how women respond to caffeine and exercise is phases in the menstrual cycle. Although this factor was controlled for in the present study, as participants were in the same phase of their menstrual cycle during the time of data collection. It is possible that results may differ depending on the phase of the menstrual cycle utilized. Another factor that may account for the lack of differences between repetitions until failure following caffeine ingestion was participant's resistance training history. The criterion for resistance training history applied to individuals participating in the present study was at least two months, for 2-4 days per week. Participant's resistance training history varied between 2-5 years. It is possible that caffeine may not impact muscular endurance performance when participants are already resistance trained. Additionally, the lack of differences in repetitions following caffeine and placebo could be accounted for by the amount of caffeine provided to participants (300 mg). Participants in the study were considered moderate caffeine drinkers, ingesting an average of 209.18 mg of caffeine per day, 5.18 days a week. It is possible that the amount of caffeine provided to participants was not enough to create an ergogenic effect and improve performance. Future studies should consider examining the effects of caffeine on muscular endurance performance in sedentary women who are non-caffeine drinkers.

The second hypothesis stated that caffeine would result in participants reporting a lower RPE compared to placebo during the leg extension and chest press. Results concluded that caffeine did have an impact on participant's rating in RPE during three sets of the chest press, as it was significantly lower compared to placebo. Results showed that RPE significantly increased from set one to set two, and from set one to set three, but not from set two to set three following caffeine ingestion. However, RPE significantly increased from two set three following placebo. This suggests that caffeine resulted in participant's perceiving the exercise to be significantly easier during the final set of the chest press exercise, while it was much harder on the final set following placebo ingestion. Results showed no significance in RPE following caffeine ingestion compared to placebo on the leg extension. Past research on this topic has been inconsistent. Green et al. (2007) and da Silva et al. (2010) found no significance with caffeine and RPE during the leg press and bench press, while significant increases were found in repetitions until failure during both exercises. Duncan, Smith, Cook, & James (2012) reported a significant effect of caffeine on RPE after the conclusion of four resistance exercises to failure in moderately trained men. Researchers of this study suggest that using only one or two exercises may not produce a change in RPE. Perhaps utilizing more exercises in a protocol may have produced different results. A possible explanation why no significant difference between conditions was found in RPE during the leg extension compared to the chest press, is pre-fatigue. A participant's lower body may have been pre-fatigued to some extent, as those muscles are used in activities of daily living. There are also no studies to date that have examined the effects of caffeine on RPE during resistance exercise in women. Future researchers should consider utilizing RPE while examining the effects of caffeine in women.

The third hypothesis states that caffeine would result in participants rating a lower pain perception compared to placebo during the leg extension and chest press. There were no significant differences in pain perception between conditions during the leg extension and chest press. It has been established that caffeine ingestion reduces pain perception during aerobic activity, while it is less clear whether it has an effect during activity where near maximal or maximal effort occurs, such as repetitions until failure. Few studies have tested this, which have led to inconsistent results. Main findings on this topic include a significantly reduced pain perception in moderately trained males following repetitions to failure during one set of four resistance exercises by Duncan et al. (2012). Conversely, Astorino et al. (2011) reported no significant changes in pain perception following to repeated bouts of isokinetic knee extension and flexion in resistance trained men. It is possible that caffeine does not reduce pain perception when performing an exercise to exhaustion. Like RPE, few studies have examined the effects of caffeine on pain perception in women; further studies should look into this.

Limitations

There were limitations in the present study that may have attributed to the results found. A small sample size was a limitation of the study. A small power size was observed for the effect of the condition on the variables, although, similar studies have reported significance with a similar number of subjects. A point of interest is the fact that differences between conditions in pain perception during the leg extension resulted in a p-value of 0.094. A statistical significance may have been found with a larger sample size. Other confounding variables could have also impacted participant's performance in the study. Participant's sleep and nutritional habits they had prior to testing could have impacted the participant's ability to perform to the best of their effort. During multiple exercise sessions, the air conditioning was not functional in the James G.

Mill Fitness Center, which raised the room temperature. This also could have impacted participant's performance. As previously stated, another limitation of the study could have been participant's resistance training history. Participants of the study had a range of resistance training history of two to five years, in this event; participant's who are more experienced in resistance training may not be affected as much by an ergogenic aid compared to a sedentary individual. Future research should make strong attempts to utilize individuals with similar experience in resistance training.

Recommendations for Future Research

The effect of caffeine on muscular endurance performance in resistance trained women still remains unclear. While results of the present study revealed no significant effect of caffeine upon muscular endurance performance on this population, the literature surrounding this topic is limited. Future studies should continue to focus on how caffeine affects muscular endurance performance in women. Future studies should also look into including more exercises into their protocol to more effectively mimic a typical resistance training session. It is possible that an impact of caffeine may not be seen until later on in an exercise session, as it is well established that caffeine produces a positive effect during activity of a longer duration. As previously stated, few studies have examined the effects of caffeine on muscular endurance in women. To our knowledge, Goldstein et al. (2010) is the only study to date to do this, while no studies have examined perceptual responses, such as RPE and pain perception on women during muscular endurance performance. Considering this is a pilot study, further investigation is needed to truly determine if there are differences in the effect of caffeine upon men and women during muscular endurance performance. This study can possibly lead to the assumption that there are gender differences in the effect of caffeine ingestion on resistance exercise performance. Future researchers should consider examining muscular endurance performance and perceptual responses on women. Studies should also consider testing sedentary populations, as resistance trained women may not be effected by ergogenic aids.

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Appendix A

Recruitment Flyer

Caffeine and Resistance Training Study

Have you ever wondered how caffeine impacts exercise performance??

Be part of an important research study

- Are you a female between 18-25 years of age?
- Do you drink no more than 300mg of caffeine per day? (about 3 cups of coffee)
- Have you been lifting weights for more than 2 months 2-4 times per week?
- Are you a nonsmoker?

If you answered yes to these questions, then you may be eligible to participate in this study.

This study will be conducted on Indiana University of Pennsylvania's Campus at the James G. Mill Fitness Center in Zink Hall.

If interested, please contact Stephanie Bartlam at **S.A.Bartlam@iup.edu** for more information

THIS PROJECT HAS BEEN APPROVED BY THE UNIVERSITY OF PENNSYLVANIA INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN RIGHTS SUBJECTS (Phone: 724-357-7730).

Appendix B

Permission for Recruitment E-mail from Department Chair

Dear Dr. Blair,

I am writing this letter to ask permission to survey your students in the spring, 2017 semester. With your permission, I will be conducting research that will examine the effects of caffeine ingestion on muscular endurance performance and their perception of pain and effort in resistance trained females.

The purpose of this study is to investigate the effect of ingesting caffeine prior to a resistance training protocol. This study will mostly take place in the James G. Mill Fitness Center where participants will be performing a muscular endurance protocol twice. Participants will be performing two exercises (leg press and chest press) with three sets of repetitions until failure. At the completion of each set participants will be asked to rate their perception of exertion and pain in their muscles during the exercise. Heart rate and blood pressure will be monitored throughout the protocol.

As the department chair or coach whose class I am seeking participants in, I am writing to specifically request approval to enter department classes in the spring, 2017 semester. I have attached a form to be completed and returned to myself at your earliest convenience. If there are any further questions, please feel free to contact me with any further questions you may have.

Thank you very much for your consideration and time.

Principle Investigator:
Stephanie Bartlam, B.S
Graduate Assistant
Kinesiology, Health and Sport Science
S.A.Bartlam@iup.edu
(724)-799-1743

Co-Investigator:
Dr. Mark Sloniger, Ph.D.,
Associate Professor, Kinesiology,
Health, & Sport Science
Sloniger@iup.edu
(724)-357-5508

Site Approval Form:

Please Check One

_X_ YES, I give you permission to recruit in KHSS classes.

______ NO, I do not give you permission to recruit in KHSS classes.

Name Elaine Blair

Signature [signature]

Date 2/6/17

Thank you again for your consideration

Stephanie Bartlam

Appendix C

Pre-Screening Verbal Check List

Once individuals contact the principal investigator to express interest in the study, these questions will be asked to determine eligibility.

1. Are you between the ages of 18-25?
2. Do you weight between 110-220 pounds?
3. How much caffeine do you drink on average on a daily basis?
4. Do you exprepperience adverse effects of to a certain amount of caffeine? (jitteriness, nausea, anxiety, elevated heart rate, etc.)
5. Are you currently participating in a weight lifting program? If so, how long and how many days per week do you typically train?
6. Do you compete in weightlifting competitions?

Appendix D

Informed Consent

Principle Investigator:

Stephanie Bartlam

Exercise Science Graduate Assistant

S.A.Bartlam@iup.edu

Co-Investigator:

Dr. Mark Sloniger, Ph.D

Associate Professor, Kinesiology of

Health, & Sport Science

Sloniger@iup.edu 724-357-5508

You have been invited to participate in this research study on a voluntary basis. When reading through this consent form, you are advised to contact us via the principal investigator listed above if you have any questions. The purpose of this study is to determine if caffeine will have an effect on your ability to perform an upper and lower body resistance exercise (lifting weights) as many times as you can until you can no longer lift the weight. It will also determine if caffeine has an impact on your perception of physical effort and pain during the activity.

You were invited to participate in this study because you are an apparently healthy adult female. You resistance train at an intermediate level of at least 2 months, 2-4 days per week, you do not compete in weight lifting competitions and you do not take in more than 300 mg of caffeine per day (3 cups of coffee). Additionally, you do not have high blood pressure or are on blood pressure medication, you are not on anti-anxiety medication, nor do you take any pain medication on a daily basis. You do not have any musculoskeletal injuries, you do not smoke cigarettes, you are not pregnant nor do you take oral contraceptives (birth control pills). You also do not have any known allergies to the following ingredients: allergic to sugar, dextrose, gum base, caffeine, glycerin, corn syrup, aspartame, acesulfame, maltodextrin, sucralose, or artificial flavoring, resinous glaze, carnauba wax, neotame, or soy lechiten. If any of these statements are not accurate, please notify the principle investigator immediately.

All potential participants who meet the criteria will be asked to report to the James G. Mill Fitness Center in Zink hall for assessments of resting heart rate and resting blood pressure. You will be weighed on a scale to determine if you meet the weight criteria (110-220lbs.). You will be provided a list of products/medication to abstain from 48 hours prior to the day you come to the fitness facility for the exercise session to ensure there are no outside factors that can impact your performance. It is important that you get a good night's sleep and avoid any vigorous activity the day before the protocol. The principal investigator will demonstrate the exercises to be performed during the study. You will then be taken through an exercise assessment to test your one repetition maximum. A one repetition maximum is the greatest amount of weight you can lift with proper form one time. You will begin this assessment by warming up performing a warm up with light weights. You will choose an initial weight that you can easily lift five to ten times. The weight will continually increase until you can no longer lift the weight. The last weight lifted and recorded will be determined as your one repetition maximum. The principal investigator will calculate 60% of that one repetition maximum to determine the weight that will be lifted for the exercise sessions. You will then perform each exercise one time to get you acquainted and comfortable lifting the weight until exhaustion and rating a number of scales accurately. The second session will then be the muscular endurance protocol. When you arrive, you will have your heart rate and blood pressure. You will then chew two pieces of caffeinated gum (200 mg), or you will receive two pieces that do not contain caffeine (placebo). You will not know if you are receiving the caffeine or the placebo. You will be then asked to sit quietly. After 10 minutes, you will dispose the gum and be asked to chew one more piece of caffeinated (100 mg) or placebo gum. You will sit quietly for five more minutes. After this duration you will have your heart rate and blood pressure taken to ensure safety. After this you will be escorted to the James G. Mill Fitness center where you will warm up by walking on a treadmill for five minutes at a slow speed. After the warm up you will begin the protocol. You will perform the leg extension and chest press, three sets of each exercise. You will lift your designated weight as many times as you can until you can no longer lift the weight to a certain pace set by a metronome(60 beats per minute). You will be asked to rate how hard you feel the exercise is. After you can no longer lift the weight, you will rest for three minutes. Immediately after your final repetition, you will be asked to rate your perception of pain and effort. Your heart rate and blood pressure will be taken by the principal investigator during the rest periods. After five minutes, you will begin the second exercise (chest press) and will go through the same procedure as the first exercise. At the end of the exercise session, you will be taken through a cool down which will consist of light upper and lower body stretching. During the third exercise session, you will be asked to repeat the protocol performed in the second session. The only difference between the sessions is whether you receive caffeinated gum or placebo.

If you choose to participate in this study, you will be asked to participate in three sessions including today for approximately one hour each session. Therefore, this study will require approximately three hours of your time. It is important to understand that you will not be required to participate in exercise that is beyond your physical ability. It is also important to note the potential side effects that could follow the ingestion of caffeine. Rare side effects include nervousness, restlessness, nausea, anxiety, agitation, and increased heart rate/blood pressure. We have selected an appropriate and safe amount of caffeine to ingest that will ensure you are ingesting a moderate amount of caffeine (3-6 mg/kg of body weight), which is equal to approximately three cups of coffee. Although this caffeinated gum has not been FDA approved, it has been shown to be safe and effective in clinical studies conducted by military research institutes and organizations within the United States. The gum has been approved for usage for U.S. military personnel. No adverse effects have been reported from this gum.

If your heart rate and blood pressure elevates to unsafe levels and you experience adverse effects of the caffeine, you will rest and be continually monitored by the principal investigator and other designates. If heart rate and blood pressure do not drop, you will be advised to visit IUP’s Center for Health and Well-Being located at 901 Maple Street, in the Suites of Maple East (724-357-9355). If you are still experiencing adverse effects, 911 emergency responders will be called per Zink Hall emergency response protocol. These adverse effects are not expected to occur. There is also a potential that you will feel muscle soreness following the exercises. This is not expected to be greater than what you would feel after a typical work out.

Benefits you may receive from participating in this study, you will gain insight to your maximal strength from performing one-repetition maximums in both the leg and chest press exercises. Further benefits include knowledge regarding physical performance to muscular fatigue. Understanding these concepts will allow you to apply resistance training principles within your own programs to improve your muscular and overall health.

Your participation is strictly on a voluntary basis and you may decide to withdrawal at any point without penalty by contacting the principle investigator or the co-investigator. Results of the study may be presented at public conferences and publications, but there will be no individual results. All results will be in presented in aggregate form. All data collected during the study will be kept for three years in compliance with federal regulations in a place that will only be accessible to the principle investigator. The research team greatly thanks you for your interest and looks forward to working with you throughout the study.

THIS PROJECT HAS BEEN APPROVED BY THE UNIVERSITY OF PENNSYLVANIA INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN RIGHTS SUBJECTS (Phone: 724-357-7730).

Department of Kinesiology and Health and Sport Science

VOLUNTARY CONSENT FORM:

I have read and understand the information provided in the informed consent form. I volunteer to be a participant in this research study. I understand that there is no compensation for my participation. I understand that all of my data is kept confidential and is only seen by the lead researcher, and I have the right to withdrawal at any time during the study without penalty. I have received an unsigned copy of the informed consent form to keep in my possession. I understand and agree to the conditions of this study as described.

Name (please print): ____

Signature: ____ Date: ______________________________

Phone number or location where you can be reached: ____

Best days to reach you: ____

I certify that I have explained to the above participant the purpose and nature of this study, and potential risks and benefits associated with participating in this study. I have answered any questions the participant posed, and have witnessed the above signature.

Investigators Signature: ______________________________ Date: ______________________________

Appendix E

Demographics/Medical History Questionnaire

Name: ___________________________ Date: _______________

Weight: ________

1. Do you consume caffeine on a daily basis? If so how much and what kind of caffeine (ie coffee, tea, energy drinks, etc.)

2. Do you have any intolerance to caffeine? If so, please explain
   a. Yes
   b. No

3. What is your age?

4. What is your gender
   a. Male
   b. Female
5. What is your race/ethnicity?
   a. White, non-Hispanic
   b. African American
   c. Hispanic
   d. Asian
   e. American Indian or Alaska Native
   f. Native Hawaiian or other Pacific Islander
   g. Other: _______________

6. What is your year of study at IUP?
   a. Freshman
   b. Sophomore
   c. Junior

    d. Senior
    e. Graduate

7. Do you have high blood pressure or are currently taking any blood pressure medication? If so, please list.

8. Do you have any cardiovascular, pulmonary, or metabolic disease that could limit your ability to perform a resistance training protocol?
    a. Yes
    b. No
9. Do you have any musculoskeletal injuries that could limit your ability to perform a resistance training protocol?
    a. Yes
    b. No

10. Are you pregnant or taking oral contraceptives (birth control pills)
    a. Yes
    b. No

11. Are you currently on any pain medication/pain killers that you need to take on a daily basis?
    a. Yes
    b. No

12. Are you currently on any anti-anxiety medication that you take on a daily basis?
    a. Yes
    b. No

13. Do you smoke cigarettes?
    a. Yes
    b. No

14. Are you currently participating in a weight lifting program?
    a. Yes
    b. No

15. If so, how long have you been lifting weights and how many times per week on average do you lift?

16. Please list any other medications you are currently taking and what you are taking them for

17. Do you have any known allergies to the following products?

Sugar

Dextrose

Gum base

Caffeine

Glycerin

Corn Syrup

Aspartame-Acesulfame

Maltodextrin

Sucralose

Artificial Flavoring

Resinous Glaze

Carnauba Wax

Neotame

Soy Lechiten

Appendix F

Caffeinated Products to Abstain from Form

Caffeinated Products and medication to abstain from:

48 hours prior to your protocol, it is important to abstain avoid any caffeinated products and pain medications/pain killers. You are also advised not to consume any alcohol or participate in any vigorous activity the day before the protocol. Not abiding by these factors could impact the results of your exercise protocol.

Below is a list of caffeinated products to avoid:

- Coffee
- Soda/Pop
- Iced Tea
- Chocolate
- Tea(black, green white)
- Hot chocolate
- Ice Cream
- Any type of energy drink (red bull, monster, rock star)
- 5 Hour energy drinks
- Pre-workout

Below is a list of medication to abstain from

- Vicodin
- Percocet
- Oxycodone
- Acetaminophen
- Naproxen (Aleve)
- Ibuprofen (advil, Excedrin, motrin, Excedrin
- Aspirin
- NSAIDS:
  - fenoprofen (Nalfon)
  - flurbiprofen (Ansaid)
  - ketoprofen (Oruvail)
  - oxaprozin (Daypro)
  - diclofenac sodium (Voltaren, Voltaren-XR, Cataflam)
  - etodolac (Lodine)
  - indomethacin (Indocin, Indocin-SR)
  - ketorolac (Toradol)
  - sulindac (Clinoril)
  - tolmetin (Tolectin)

- meclofenamate (Meclomen)
- mefenamic acid (Ponstel)
- nabumetone (Relafen)
- piroxicam (Feldene)

Appendix G

One-Repetition Maximum Protocol

An assessment that involves the determination of the highest weight one can lift through full range of motion and with proper form. This protocol is based on National Strength and Conditioning Association's Guidelines

The one repetition maximum assessment will go as followed:

1. The subject will warm up with a light weight where they can easily perform 5-10 repetitions. A one minute rest period will follow.
2. The subject will then select a weight where they will be able to perform 3-5 repetitions by adding 10-20 pounds for the bench press, and 30-40 pounds for the leg press. The subject will then rest for two minutes after completing these repetitions,
3. The subject will use a weight that is estimated they will be able to perform three times. The subject will rest for 2-4 minutes
4. The subject will then attempt a one-repetition maximum.
5. If the subject was successful, or was able to complete more than one repetition, there will be another load increase of 10-20 pounds for the bench press, and 20-40 pounds for the leg press.
6. If the subject failed, there will be a 2-4 minute rest period, and then a decrease in load.
7. The last resistance used where the subject can only perform one repetition will be considered their one-repetition maximum.

Appendix H

Physician's Scale

A tool that is used to measure an individual's height and weight. The scale used in this study is located in the James G. Mill Fitness center. This tool was used to determine participant's body weight to ensure they fit the weight criteria.

Appendix I

Polar FT1 Heart Rate Monitor™

Polar FT1 heart rate monitors are used to measure heart rate at rest and during exercise. This monitor consists of a transmitter that is fastened to an elastic strap worn below the chest muscles and a watch worn around the wrist. There are two grooved electrodes on the back of the transmitter that transmits the heart rate signal to the watch where the heart rate is displayed. Participants heart rate was measured at rest pre and post ingestion of gum (caffeine or placebo), and after the final failed repetition of each set of each exercise.

Appendix J

Blood Pressure Cuff

This tool is used to assess systolic and diastolic blood pressure. It is commonly referred to as a blood pressure cuff or aneroid sphygmomanometer. Participant’s blood pressure were taken pre and post ingestion of gum (caffeine or placebo), and after the final failed repetition of each set of each exercise.

Appendix K

ACCUSPLIT Survivor III S3MAGXLBK Stopwatch ™

A watch with a hand or a digital display that can be started and stopped at will for exact timing. The timer was used in this study to keep time of rest periods between sets and exercises

Appendix L

OMNI Perceived Exertion Scale for Resistance Exercise

A numerical and visual scale rated from 0-10 used for individuals during resistance training to rate how much muscular effort they feel. (Robertson et al., 2003) Participants were asked to rate their OMNI RPE following the final failed repetition of each set of each exercise.

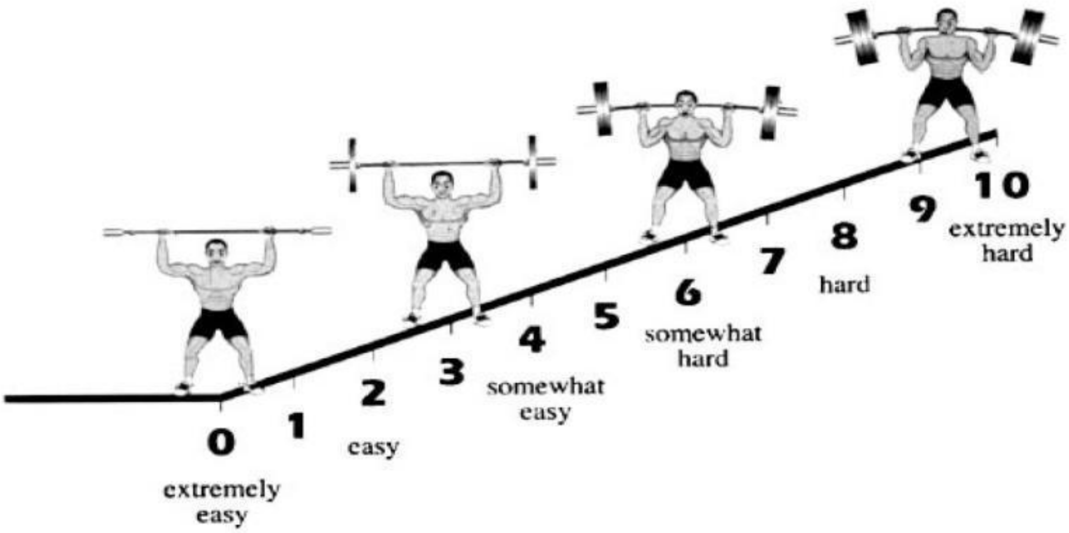

FIGURE 1. OMNI Perceived Exertion Scale for Resistance Exercise.

Appendix M

Pain Perception Scale

A numerical scale rated from 0-10 that is defined as the intensity of pain an individual feels. In this setting, pain is referred to a burning or stinging sensation any individual can feel when lifting weights. (Cook, 1998)

0- No pain at all

½-Very faint pain

1- Weak pain

2- Mild pain

3-Moderate pain

4-Somewhat strong pain

5- Strong pain

7- Very strong pain

10- Extremely intense pain

Appendix N

Metronome

A device that produces regular, metrical ticks (beats, clicks) —it is set in beats per minute set in beats per minute. The Metronome App. ™ was used to ensure participants were performing the exercises at the same tempo.

Appendix O

Precor Treadmill E956I ™

A cardiovascular machine with a continuous belt that allows individuals to walk or run. Participants warmed up on the treadmill by walking for five minutes at 3.0 mph with 0% grade.

Appendix P

Leg Extension Procedure

The leg extension procedure was performed on a Magnum Fitness Systems Leg Extension Machine (E Series, 1221), the procedures of the leg extension are as followed by the National Strength and Conditioning Association Guidelines (Haff & Triplett, 2016).

Beginning Phase:
1. Sit down in machine and press the back firmly against the pad.
2. Place ankles behind and in contact with the foot roller pad.
3. Position legs parallel to each other
4. Align knees with the axis of the machine. If necessary, adjust the back pad or the roller pad to position the knees
5. Grasp the handles or the sides of the seat

Upward Movement Phase:
1. Raise the roller pad by fully extending the knees.
2. Keep the torso erect and the back firmly pressed against the back pad.
3. Maintain a firm grip on the handles or the sides of the seat.
4. Do not allow the hips or buttocks to lift off the seat.
5. Do not forcefully lock out the knees.

Downward Movement Phase:
1. Allow the knees to slowly flex back to the beginning position.
2. Keep the torso erect and the back firmly pressed against the back pad.
3. Maintain a firm grip on the handles or the sides of the seat.

Major Muscles involved:

Vastus Lateralis, vastus intermedius, vastus medialis, and rectus femoris.

Appendix Q

Chest Press Procedure

The chest press procedures were performed on a Magnum Fitness Systems Chest Press Machine (E Series,1221). The chest press procedures are as followed by the National Strength and Conditioning Guidelines (Haff & Triplett, 2016)

Starting Position:

1. Sit down and lean back on the seat in the five-point body contact position.
2. Grasp the handles with a closed, pronated grip.
3. Align handles with the nipples. If necessary, adjust the seat height to correctly position the handles.
4. All repetitions begin from this position.

Forward Movement Phase:

1. Push the handles away from the chest to a fully extended elbow position.
2. Do not arch the lower back or forcefully lock out the elbows.
3. Maintain five-point body contact position.

Backward Movement Phase:

1. Allow the handles to slowly move backward to the starting position.
2. Maintain the five-point body contact position.

Major Muscles Involved:
Pectoralis major, anterior deltoids, and triceps brachii