# ABSTRACT

## THE EFFECTS OF ACUTE CAFFEINE INGESTION ON REPEATED-SPRINT PERFORMANCE IN COLLEGE-AGED NON-ATHLETES

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Caffeine is one of the most widely used drugs in the world, commonly ingested in coffee, tea, soda, chocolate, and energy drinks, due to its benefits of increasing mental and physical capabilities. Caffeine has also been commonly used as an ergogenic aid when performing repeated-sprint activity. PURPOSE: The purpose of this study is to examine the effects of 200 mg of caffeine during repeated-sprint activity on heart rate, rating of perceived exertion, blood lactate concentration, and sprint time. METHODS: Thirty-two students (Age: 22.19 ± 2.29 years; Height: 170.58 ± 10.18 cm; Weight: 74.78 ± 12.76 kg; BMI: 25.59 ± 2.78) participated in the study. The study followed a randomized crossover trial, in which each participant ingested either 200 mg of caffeine (CAF) or placebo (PLA) 45 minutes prior to each of the two exercise sessions. The sprinting protocol consisted of three sets of six maximal-effort 30-meter sprints. Each single sprint covered a 15-meter distance between the starting line and the secondary marker, such that each subject sprinted down to the secondary marker and back to the starting line. Each of the six sprints in a set were separated by a total of 20 seconds using an active recovery modality. Following each sprint set, heart rate, blood lactate concentration, sprint time, and the rating of perceived exertion were recorded. RESULTS: The caffeine trials were not significantly different than the placebo trials for heart rate and the rating of perceived exertion. However, for the rating of perceived exertion, there was a main effect for time [$F(3,93) =$

292.810, p < 0.001]. The caffeine trials (Resting: 1.30 ± 0.52 mmol/L; Set 1: 11:33 ± 2.38 mmol/L; Set 2: 13.26 ± 3.02 mmol/L; Set 3: 13.67 ± 2.49 mmol/L) elicited increased blood lactate concentrations compared to the placebo trials (Resting: 1.37 ± 0.53 mmol/L; Set 1: 9.24 ± 2.43 mmol/L; Set 2: 11.46 ± 2.87 mmol/L; Set 3: 11.83 ± 2.55 mmol/L). The caffeine trials (Set 1: 6.78 ± 0.58 secs; Set 2: 6.81 ± 0.55 secs; Set 3: 6.85 ± 0.57 secs) also produced a decreased average sprint time compared to the placebo trials (Set 1: 7.00 ± 0.64 secs; Set 2: 7.02 ± 0.62 secs; Set 3: 7.12 ± 0.63 secs). For the average sprint time, there were significant main effects for condition [F(1,31) = 36.839, p < 0.001] and time [F(2,62) = 5.806, p = 0.006]. CONCLUSION: Caffeine supplementation at a dose of 200 mg elicits an increase in repeated-sprint ability in college-aged non-athletes.

*Keywords: caffeine, ergogenic aids, repeated-sprints, performance*

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# THE EFFECTS OF ACUTE CAFFEINE INGESTION ON REPEATED-SPRINT PERFORMANCE IN COLLEGE-AGED NON-ATHLETES

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# CHAPTER 1

## INTRODUCTION

Caffeine is one of the most widely used drugs in the world, commonly ingested in coffee, tea, soda, chocolate, and energy drinks, due to its benefits of increasing mental and physical capabilities (Astorino & Roberson, 2010; Davis & Green, 2009). It is also present in widely consumed over-the-counter medications such as analgesics and diuretics. In the United States, 90% of adults reported consuming caffeine on a daily basis (Astorino & Roberson, 2010). Many individuals also use caffeine as an ergogenic aid to enhance exercise performance (Woolf, Bidwell, & Carlson, 2008).

Caffeine is completely absorbed within the stomach 45 minutes after ingestion and has a half-life in the body of about 3-4 hours (Astorino & Roberson, 2010). Research has suggested that exercise performance may be improved by ingesting as little as 150–250 mg of caffeine, which is equivalent to about 1 to 2 cups of coffee (Anselme, Collomp, Mercier, Ahmaidi, & Prefaut, 1992; Collomp, Ahmaidi, Chatard, Audran, & Prefaut, 1992; Wiles, Bird, Hopkins, & Riley, 1992). The majority of research investigating the effects of caffeine supplementation on exercise performance used doses ranging from 5-13 $mg \cdot kg^{-1}$ of body mass (Spriet, 2014). This dosage range has been reported to cause gastrointestinal discomfort, headaches, and dizziness, while the limited research that studied lower dosages ($\leq 3$ $mg \cdot kg^{-1}$ of body mass) presents that lower doses offset these undesirable side effects (Spriet, 2014). Literature also suggests that

caffeine enhances endurance and improves performance during prolonged and exhaustive exercises (Woolf et al., 2008). It has been further proposed that caffeine increases mental alertness, enhances concentration, and reduces fatigue (Woolf et al., 2008). The prospective effects of caffeine on exercise performance have been extensively explored, but primarily in endurance exercises.

Short-term bouts of exercise, with limited recovery, over prolonged periods of time are imperative to performance in team sports (Carr et al., 2008). The term "repeated-sprint ability" (RSA) has been proposed by sports scientists and coaches alike to play an important factor in sport performance (Spencer, Bishop, Dawson, & Goodman, 2005). Repeated-sprints is a form of high-intensity interval training (HIIT) that can produce physiological benefits through training. Athletes participating in a HIIT-based training regimen can experience an improvement in maximal oxygen consumption, production, resynthesis, utilization of adenosine triphosphate (ATP), resynthesis of phosphocreatine (PCr), myoglobin content, peak power, and time-to-exhaustion at maximal power output (Laursen & Jenkins, 2002). Along with the previously mentioned physiological benefits, HIIT training can improve increased fat oxidation, resting glycogen content, reduced rate of glycogen diminishment, improved vascular structure and function, and reduced lactate accumulation in non-athletes (Gibala, Little, MacDonald, & Hawley, 2012).

Research has shown that caffeine supplementation increases endurance performance, but the efficacy of caffeine ingestion on high-intensity short duration activities is equivocal (Davis & Green, 2009). Repeated-sprint activity primarily utilizes the phosphagen and anaerobic glycolytic pathways to produce anaerobic energy (Haff & Triplett, 2016). These energy

pathways are able to quickly provide energy at large quantities for short periods of time (McArdle, Katch, & Katch, 2014). Further, the nature of anaerobic metabolism allows sufficient amounts of energy to fuel the body for high-intensity short-duration activities such as repeated-sprinting.

There have been several proposed mechanisms of how caffeine increases performance during exercise. The most common theory is through increasing fat oxidation and glycogen-sparing mechanisms. It is unlikely that a theory based on amplifying oxidation of fatty acids would affect exercise performance commanded by oxygen-independent pathways (Davis & Green, 2009). Therefore, central and peripheral mechanisms related to adenosine, pain perception, catecholamines lactic acid, potassium, and calcium are the most likely theories that affect anaerobic exercise performance.

Little research has been produced that investigates the effects of caffeine ingestion on repeated-sprint ability. Furthermore, even fewer studies pinpointed caffeine's effect on repeated-sprint running ability. Some studies suggest caffeine increases repeated-sprint ability (Carr et al., 2008; Del Coso et al., 2012; Goods, Landers, & Fulton, 2017; Paton, Lowe, & Irvine 2010; Pontifex, Wallman, Dawson, & Goodman, 2010; Schneiker, Bishop, Dawson, & Hackett, 2006), while other studies find that caffeine has a negligible effect (Clarke et al., 2016; Ermolao et al., 2017; Paton, Hopkins, & Vollebregt, 2001). Because of the widespread use of caffeine, the participation in recreational team sports, and the programming of high-intensity interval training, further research is needed to investigate the efficacy of caffeine on repeated-sprint ability. Most of the studies that investigated caffeine's effect on repeated-sprint ability focused on trained athletes and used a relative dosage. Therefore, the use of an absolute dosage of caffeine along

with investigating the effects on college-aged non-athletes should be explored. The purpose of this study is to examine the effects of 200 mg of caffeine on repeated-sprint performance in college-age non-athletes. It is hypothesized that 200 mg of caffeine will result in a slight ergogenic effect during repeated-sprints. Additionally, it is hypothesized that there will be an increase in heart rate and a decrease in the rating of perceived exertion with caffeine supplementation. Furthermore, it is hypothesized that there will be a decrease in total sprint time while exhibiting a slight increase in blood lactate concentrations after each set.

# CHAPTER 2

# REVIEW OF THE LITERATURE

## Anaerobic Metabolism

Individuals participating in certain team sports, such as football and basketball, are required to perform repeated-sprint efforts of maximal or near-maximal intensity (Spencer et al., 2005). To perform at such intensities, specific energy systems must be activated. Therefore, it is imperative to highlight the metabolic effects of repeated-sprint activity and the processes energy substrates must go through to be converted into usable energy. Like other forms of physical activity or exercise, repeated-sprint activity utilizes specific energy systems to aid in fueling the body. The aerobic system is primarily used to generate energy for muscle contraction at rest and during low intensity activities, while using carbohydrates and fats as substrates with the help of oxygen ($O_2$) (Haff & Triplett, 2016). Along with providing energy for low intensity activities, the aerobic system produces adenosine triphosphate (ATP) at a slow rate (Kenney, Wilmore, & Costill, 2015). Therefore, a different energy system is needed for early muscle contraction in the first few minutes of exercise. Since repeated-sprint activity requires efforts of maximal or near-maximal intensities along with short bouts of muscle contraction, the aerobic system would not be an ideal energy system to supply the working muscles for maximum performance (Spencer et al., 2005). For that reason, a more rapid metabolic process is needed to supply the requisite energy for the active muscles.

Anaerobic metabolism is the muscle's capability of generating ATP through metabolic pathways without the use of oxygen (Powers & Howley, 2009). Repeated-sprint activity requires anaerobic metabolism to produce energy at a high rate using fats and carbohydrates (Haff & Triplett, 2016). In anaerobic metabolism, the rate of ATP synthesis is up to five to six times greater than in aerobic energy systems (Lamb & Murray, 1999). In both aerobic pathways and anaerobic pathways, ATP is converted from adenosine diphosphate (ADP) and inorganic phosphate ($P_i$) (Powers & Howley, 2009). As stated prior, oxygen is used for aerobic metabolism to produce and resynthesize ATP, but anaerobic metabolism can yield ATP without the presence of oxygen (Kenney, Wilmore, & Costill, 2015). The two energy systems that aid in anaerobic metabolism are the ATP-PC system, or phosphagen system, and the anaerobic glycolytic system (Powers & Howley, 2009). The main difference between the two is the point in time when the metabolic process is activated in relation to exercise and the process of how substrates are converted into energy. The phosphagen system provides energy for muscular contraction at the beginning of exercise and during short-term, high-intensity bouts of exercise (Powers & Howley, 2009). The two sources of energy in the phosphagen system are ATP and phosphocreatine (PCr). The glycolytic system, which is used during intense, short-duration exercise, activates once the ATP and PCr stores are depleted (McArdle, Katch, & Katch, 2014). Both the phosphagen system and the anaerobic glycolytic system aid in anaerobic metabolism, which is the primary pathway to fuel the human body during repeated-sprint activity (Spencer, Bishop, Dawson, & Goodman, 2005).

## Phosphagen System

The phosphagen system, which is the first metabolic pathway of anaerobic metabolism, is activated to produce high amounts of energy in the first 10-15 seconds of high-intensity exercise (McArdle, Katch, & Katch, 2014). In the phosphagen system, energy exclusively comes from ATP and PCr (Kenney, Wilmore, & Costill, 2015). Each kilogram of skeletal muscle contains 3 to 8 mmol of ATP, containing up to three times more PCr. ATP stores within the muscle cells are utilized in the first 2-3 seconds then the cells switch to the use of PCr to secure the preservation of ATP for intracellular processes (Hargreaves & Spriet, 2006; McArdle, Katch, & Katch, 2014). The release of energy from PCr is catalyzed by creatine kinase, which acts on PCr to separate $P_i$ from creatine. The released energy can then be used to add a $P_i$ molecule to an ADP molecule to form ATP. The energy released from ATP by splitting the phosphate group results in the break-down of PCr, thus providing energy and $P_i$ to resynthesize ATP from ADP (Kenney, Wilmore, & Costill, 2015). Stored PCr, which equals to about 11.1 kcal, becomes depleted after 3-15 seconds of high intensity exercise (Brooks, Fahey, & Baldwin, 2004). Complete resynthesis of ATP occurs within 3 to 5 minutes of recovery, whereas PCr resynthesis occurs within 8 minutes of recovery (Haff & Triplett, 2016). Due to the nature of repeated-sprint activity, an additional energy system must be activated because of the insufficient time to replenish ATP and PCr stores. Therefore, the anaerobic glycolytic system produces the remainder of energy needed to support the metabolic demands of high-intensity exercise (McArdle, Katch, & Katch, 2014).

## Anaerobic Glycolytic System

Anaerobic glycolysis is the primary source of ATP production from 15-90 seconds of high-intensity exercise (McArdle, Katch, & Katch, 2014). The process of glycolysis, which

occurs in the sarcoplasm, breaks down glucose and yields 36-38 ATP molecules in 10 to 12 enzymatic reactions with the cooperation of the electron transport chain, the Krebs cycle, and depending on glycogenolysis (Kenney, Wilmore, & Costill, 2015; McArdle, Katch, & Katch, 2014). Glycogenolysis is the process in converting glycogen into glucose-1-phosphate (Kenney, Wilmore, & Costill, 2015). The net gain from the process of glycolysis is 3 mol of ATP formed for each mole of glycogen broken down. If glucose is broken down instead of glycogen, only 2 mol of ATP is formed because of the 1 mol used to convert glucose to glucose-6-phosphate (G6P; Kenney, Wilmore, & Costill, 2015).

The first enzymatic chemical reaction during glycolysis occurs when blood glucose is converted to G6P with the assistance of the enzyme hexokinase. Hexokinase aids in the transfer of a phosphoryl group from an ATP molecule to form glucose-6-phosphate (G6P), adenosine diphosphate (ADP), and a hydrogen ion ($H^+$). Once glucose-6-phosphate is formed, phosphohexose isomerase (PHI) initiates the conversion of G6P to fructose 6-phosphate (F6P). Meanwhile, phosphoglucose isomerase (PGI) completes the conversion from G6P to F6P. Phosphofructokinase (PFK), which is the enzyme needed to break down F6P, utilizes an ATP molecule to yield fructose-1 (F1), 6-bisphosphate (6DP), adenosine diphosphate (ADP), and a hydrogen ion ($H^+$). The next step in the glycolytic process occurs when F1 and 6DP splits into two phosphorylated molecules with three carbon chains, dihydroxyacetone phosphate (DHAP) and glyceraldehyde 3-phosphate (G3P). DHAP and G3P are then converted by triosephosphate isomerase (TIM) to yield two 3-phosphoglycerasdehyde (G3P). These two three-carbon chains further decompose to pyruvate in five successive reactions resulting in the production of ATP (Brooks, Fahey, & Baldwin, 2004; McArdle, Katch, & Katch, 2014).

The larger portion of adenosine triphosphate (ATP) production occurs during the last five enzymatic chemical reactions of glycolysis. Glyceraldehyde 3-phosphate dehydrogenase (GAPDH), inorganic phosphate ($P_i$), and nicotinamide adenine dinucleotide ($NAD^+$) convert G3P into 1,3-diphosphoglycerate (1,3-DPG), nicotinamide adenine dinucleotide (NADH), and a hydrogen ion ($H^+$). This chemical reaction generates the necessary NADH to be used in the electron transport chain to produce more ATP; 1, 3-diphosphoglycerate (1,3-DPG) is hydrolyzed by into a carboxylic acid by phosphoglycerate kinase with ADP and $H^+$ to produce 3-phosphoglyceric acid (3-PG) and ATP. The 3-PG molecule further breaks down into 2-phosphoglyceric acid (2-PG) with the assistance of phosphoglyceromutase. The molecule 2-PG is then broken down into phosphoenolpyruvate (PEP) and a single water molecule ($H_2O$) through the enzyme enolase. The final enzymatical chemical reaction during glycolysis involves PEP being broken down by pyruvate kinase to yield one molecule of pyruvate and one molecule of ATP (Brooks, Fahey, & Baldwin, 2004; McArdle, Katch, & Katch, 2014; Powers & Howley, 2009). Finally, during homolactic fermentation, $NAD^+$ and a non-oxidized hydrogen ion ($H^+$) split. The non-oxidized hydrogen ($H^+$) then combines with a pyruvate molecule with the assistance of lactate dehydrogenase (LDH) to yield a lactate molecule (McArdle, Katch, & Katch, 2014).

## Lactate Accumulation

Lactic acid is a product of anaerobic glycolysis that forms through the combination of a non-oxidized hydrogen ion ($H^+$) and a pyruvate molecule (McArdle, Katch, & Katch, 2014). If lactic acid is not cleared, it dissociates, thus converting to lactate and causing hydrogen ion buildup. The accumulation of $H^+$ causes muscle acidosis, which is a decrease in pH levels (Kenney, Costill, & Wilmore, 2015; McArdle, Katch, & Katch, 2014). Activities of high

intensity and a short duration, such as sprinting, heavily depend on anaerobic glycolysis. Research has shown that the maximal rate of lactate production for Type II muscle fibers is 0.5 $mmol \cdot g^{-1} \cdot s^{-1}$, while Type I muscle fibers have a maximal rate of lactate production of 0.25 $mmol \cdot g^{-1} \cdot s^{-1}$ (Dudley & Terjung, 1985; Meyer & Terjung, 1979). Therefore, anaerobic activities produce substantial amounts of lactate and $H^+$ within the muscles while reducing blood, muscle, and intracellular pH (Kenney, Costill, & Wilmore, 2015). The human body naturally produces bi-carbonate ($HCO_3$) to help counter the effects of acidosis, but an increased rate of $H^+$ and inadequate rate of clearance result in decreasing levels of pH (McArdle, Katch, & Katch, 2014). At rest, there is a low concentration of lactate in the blood ranging from 0.5 to 2.2 mmol/L of blood. Lactate levels of above 6 or 7 mmol/L of blood begin to observe a decrease in anaerobic exercise performance. Increases in exercise intensity also is effective in increasing lactate levels, which can reach up to 20 to 25 mmol/L of blood (Haff & Triplett, 2016).

Increases in lactate levels and $H^+$ buildup result in decreased muscular force production, which ultimately leads to a decreased exercise performance (Haff & Triplett, 2016). The reason for diminished force production is because of these four factors: $H^+$ interferes with calcium ($Ca^{++}$) from the sarcoplasmic reticulum, $H^+$ interferes with actin-myosin binding affinity, $H^+$ interferes with ATP hydrolysis, and $H^+$ interferes with ATP production. Without sufficient amounts of calcium being released, the thick and thin filaments of the sarcomere cannot bind due to calcium not attaching to troponin. Furthermore, without a strong affinity between actin and myosin, the force production of the muscle decreases. ATP hydrolysis deals with the mATPase enzyme that breaks down ATP for energy use. Without proper mATPase activity, insufficient amounts of ATP can be broken down for energy. Finally, without the production of ATP, an insufficient amount of energy can be utilized for muscle contraction (Haff & Triplett, 2016;

McArdle, Katch, & Katch, 2014). Consequently, these four factors relate to muscular force production in the muscles and eventually result in decreased physical performance (Haff & Triplett, 2016).

## Caffeine Mechanisms of Action

Caffeine has a specific effect on how various mechanisms of the body function and its relation to exercise and physical activity. There have been various early theories on how caffeine affects the human body, such as free-fatty oxidation and glycogen sparing. This theory has been challenged and researchers have investigated other mechanisms of how caffeine affects the body (Davis & Green, 2009). Additionally, the model of enhanced free-fatty acids would be imperative to highlight if focusing on oxygen-dependent pathways. Since the focus of this paper is the oxygen-independent pathways, the free-fatty oxidation theory has not been included in this section. The two types of mechanisms that have been explored in this section are the central and peripheral pathways in which caffeine may be ergogenic.

### Central Mechanisms

The central mechanisms of caffeine are associated with the central nervous system (CNS), which includes the brain and the spinal cord. The two main aspects that caffeine affects to alter exercise performance are adenosine and pain perception.

#### Adenosine

Caffeine is known to stimulate the central nervous system (CNS), specifically through adenosine receptor antagonism (Sawynok, 1998). Adenosine, which is proven to be an effective vasodilator, is a compound made up of adenine and ribose (Latini & Pedata, 2001). Adenosine metabolism is regulated through adenine nucleotide breakdown, which consists of adenosine

triphosphate (ATP), adenosine diphoshphate (ADP), and adenosine monophosphate (AMP). Studies have shown that adenosine concentration can be increased in skeletal muscle, smooth muscle, the circulatory system, and in the brain during exercise (Daly, 1982; Latini & Pedata, 2001). Furthermore, adenosine has been shown to enhance pain perception, induce sleep, reduce arousal, depress spontaneous locomotor activity, and act as a neuromodulator (Davis & Green, 2009). Adenosine can inhibit neurotransmitter release and neuronal firing rates by binding to central nervous system receptors. Caffeine, which has a similar molecular structure to adenosine, has been shown to counter the hindrance effects of adenosine (Davis & Green, 2009; Kalmar & Cafarelli, 1999).

The four different receptor subtypes for adenosine ($A_1$, $A_{2a}$, $A_{2b}$, and $A_3$) are shown to produce different responses to adenosine. $A_1$ receptor activation is responsible for inhibitory effects of adenosine, while $A_2$ receptors are responsible for excitatory responses (Latini & Pedata, 2001). Caffeine, which is lipophilic in nature, can cross the blood-brain barrier by simple diffusion and alter the inhibitory effects of adenosine. The effects are primarily evoked through $A_1$ and $A_2$ receptors because of their high affinity for adenosine (Davis & Green, 2009; McCall, Millington, & Wurtman, 1982). Therefore, caffeine leads to a modified pain perception while maintaining motor unit firing rates and neuro-excitability (Davis & Green, 2009).

Pain Perception

Due to the blockade of adenosine receptors, caffeine is commonly used as an over-the-counter medication for its pain-relieving effects (Davis & Green, 2009). The pain adaptation model states that pain increases the output of muscles when they become antagonists and decreases the output of muscles when acting as agonists. This reduction in the output of muscles

results in the reduction of maximum voluntary contraction (MVC), which is the ability of the muscle to forcefully contract (Lund, Donga, Widemer, & Stohler, 1991). Kalmar (2005) researched the influence of caffeine on voluntary muscle activation and found that pain has the ability to have an impact on motor unit recruitment by decreasing the firing rate. As stated prior, adenosine is proven to induce muscle pain through activation of $A_1$ and $A_2$ receptors (Latini & Pedata, 2001). With the supplementation of caffeine, the adenosine receptors become blocked, thus reducing the hyperalgesic response (Sawynok, 1998).

Studies have shown that caffeine has the ability to affect pain perception in individuals. Motl, O'Connor, and Broglio (2003) investigated the effects of caffeine on pain perception during 30 minutes of cycling and concluded that caffeine had hypoalgesic properties that blocked $A_1$ and $A_2$ receptors. Furthermore, O'Connor, Motl, Broglio, and Ely (2004) studied the dose-dependent effect of caffeine on reducing leg muscle pain during cycling and concluded that even though supplementing 10 $mg \cdot kg^{-1}$ of caffeine was more effective in reducing pain than 5 $mg \cdot kg^{-1}$, they both were significantly effective in comparison to placebo. These two studies support the idea that caffeine supplementation leads to a modified pain perception during exercise.

Even though studies have shown that caffeine can alter an individual's pain perception, that does not mean that motor unit firing rates are sustained or increased. Greer, Morales, and Coles (2006) investigated the effects of caffeine supplementation on performance on a 30-second Wingate test. The researchers found that caffeine had no effect on electromyogram (EMG) activity. Furthermore, Williams, Signorile, Barnes, and Henrich (1988) found no effect of caffeine on EMG activity during maximal and submaximal isometric hand-grip contraction. The

two previous studies found that caffeine supplementation did not show any significance in the motor unit firing rates during exercise.

The rating of perceived exertion (RPE) is a way to determine exercise intensity levels in conjunction with physiological measures (Eston, Davies, & Williams, 1987). Due to the analgesic effects of caffeine, it would seem safe to assume that caffeine supplementation can allow individuals to work at a higher intensity and prolong the duration of exercise. Doherty and Smith (2005) conducted a meta-analysis to review the effects of caffeine on RPE. There has been an abundance of studies that examined caffeine supplementation on aerobic performance, but anaerobic performance studies have been meager. Doherty and Smith (2005) found that the majority of studies showed no difference in RPE between caffeine and placebo, therefore drawing the conclusion that caffeine does not affect RPE during exercise.

## Peripheral Mechanisms

The peripheral mechanisms of caffeine deal with the peripheral nervous system, which includes the cranial nerves and the spinal nerves (Haff & Triplett, 2016). The four aspects that caffeine is theorized to affect in exercise performance are catecholamines, lactic acid, potassium, and calcium.

### Catecholamines

Catecholamines are organic compounds that are released by the adrenal medulla and act as central motor stimulators and peripheral vascular dilators; they enhance enzyme systems and aid in the release of calcium in the muscle. Catecholamines include epinephrine, norepinephrine, and dopamine. The role catecholamines play on the body is to increase force production, increase

muscle contraction rate, increase blood pressure, increase energy availability, increase muscle blood flow through vasodilation, and increase secretion rates of other hormones, such as testosterone (Haff & Triplett, 2016).

Bell, Jacob, and Ellerington (2001) and Greer, McLean, and Graham (1998) researched and concluded that caffeine supplementation increases epinephrine secretion in comparison to placebo. Jackman, Wendling, Friars, and Graham (1996) found that plasma catecholamine levels were not statistically different between caffeine and placebo during a cycle ergometer protocol but found that catecholamine levels were elevated at rest 60 minutes after ingestion of caffeine. With increased epinephrine levels in the body from caffeine supplementation, exercise performance is also augmented due to increased force production, increased muscle contraction rate, increased blood pressure, increased energy availability, increased blood flow, and increased secretion rates of other hormones (Haff & Triplett, 2016).

Lactic Acid

Lactic acid is the product of the lactate dehydrogenase reaction during glycolysis, which is associated with increased in hydrogen ions ($H^+$). Buildup of hydrogen ions results in inhibited glycolytic reactions, interference with muscle excitation-coupling contraction, inhibited calcium-troponin binding, and interference with cross-bridge recycling (Haff & Triplett, 2016). These factors have the ability to decrease overall exercise performance. A possible explanation of why caffeine increases blood lactate concentration during exercise could lie with caffeine stimulating the CNS and diminishing pain perception. Decreasing pain perception would attenuate fatigue by extending the time at which a level of pain is encountered. The extended duration of exercise at a high intensity due to the lessened pain may result in greater blood lactate accumulation through

the process of glycolysis (Davis & Green, 2009; McArdle, Katch, & Katch, 2014; Powers & Howley, 2009).

Most studies have shown that caffeine increases lactic acid concentration during aerobic exercise as well as anaerobic exercise (Davis & Green, 2009). Bell, Jacobs, and Ellerington (2001) found that caffeine, ephedrine, and a combination of the two result in higher blood lactate levels during anaerobic exercise. Carr et al. (2008) found that blood lactate levels were also significantly increased during a repeated-sprint protocol during running. Furthermore, Collomp et al. (1992) and Goods et al. (2017) established that blood lactate levels were also significantly elevated during a swim-based sprint protocol. Some studies have shown no difference in blood lactate levels when associated with caffeine supplementation. Greer et al. (1998) investigated the effects of caffeine on 30-second Wingate performance. The researchers found that caffeine ingestion had no significant effect on blood lactate levels. Additionally, Cakir-Atabek (2017) studied the effects of acute caffeine ingestion on anaerobic cycling in comparison to placebo ingestion. The results of the study showed that increases in blood lactate levels were independent of the treatments.

Potassium

Caffeine may have an effect on $NA^+/K^+$ ATPase activity, which could enhance excitation-contraction coupling (Davis & Green, 2009). In order to completely understand the effects caffeine has on enhancing excitation-contraction coupling, it is imperative to highlight the process sodium ($Na^+$) and potassium ($K^+$) play on muscular contraction. The three stages of the action potential are the resting stage, depolarization, and repolarization (McArdle, Katch, & Katch, 2014). The resting stage of the action potential occurs when the membrane potential is at

a normal resting value, -95 millivolts (mV) for skeletal muscle. Additionally, the predominant extracelluar ion is $Na^+$, while the predominant intracellular ion is $K^+$. During the depolarization stage, the acetylcholine (ACh) released by an axonal terminal of a motor neuron causes the sodium channels to open and increase in intracellular $Na^+$. This results in a reverse in polarity from -95mV to +35mV in skeletal muscle, causing muscle contraction. During the repolarization stage, the sodium channels close and the potassium channels open, causing $K^+$ to return into the cell and $Na^+$ to diffuse out of the cell. Once $Na^+$ diffuses from the cell and $K^+$ is brought back, the muscle cell is back at its resting state (Kenney, Wilmore, & Costill, 2015; McArdle, Katch, & Katch, 2014; Powers & Howley, 2009). Maintaining sufficient amounts of $Na^+$ and $K^+$ is important for forceful output of muscle contraction. Preventing a rise in plasma $K^+$ by enhanced $Na^+/K^+$ ATPase activity can potentially delay fatigue by creating a more advantageous environment for excitation-contraction (Davis & Green, 2009).

Caffeine has been shown to exhilarate resting skeletal muscle $K^+$ by increasing $Na^+/K^+$ ATPase activity during aerobic exercise (Hawke, Willmets, & Lindinger, 1999; Lindinger, Graham, & Spriet, 1993). Lindinger (1995) concluded that plasma $K^+$ concentrations during exercise showed a parallel increase with exercise intensity. Therefore, the idea that caffeine would be effective on plasma $K^+$ concentrations during high-intensity exercise must be feasible. However, Greer, McLean, and Graham (1998) showed no significant effect on diminishing plasma $K^+$ levels. Furthermore, Lindinger et al. (1993) found that certain subjects showed a decrease in plasma $K^+$ levels, highlighting that untrained individuals failed to show an attenuation. The literature states that an intensity-dependent relationship may exist for caffeine

attenuation of plasma $K^+$ and more research must be done to fully understand this area. (Davis & Green, 2009).

Calcium

The effects of caffeine have been investigated with increase calcium ($Ca^{++}$) mobilization from the sarcoplasmic reticulum (SR; Weber, 1968; Weber & Herz, 1968). To understand how increased caffeine may potentially display an ergogenic effect through calcium, it is important to highlight calcium's importance in excitation-contraction coupling. When the muscle cell depolarizes, $Ca^{++}$ is released from the SR to bind with troponin. This causes a shift in a protein molecule that runs along the length of the actin filament known as tropomyosin. With the shift in tropomyosin, the myosin cross-bridge can now attach to the actin filament, thus allowing force to be produced as the actin filaments are pulled towards the center of the sarcomere (Haff & Triplett, 2016; McArdle, Katch, & Katch, 2014).

This theory that caffeine increases $Ca^{++}$ mobilization has been investigated by Weber (1968) and Weber and Herz (1968). Weber and Herz (1968) found that caffeine ingestion exhibited an increase in $Ca^{++}$ release from the SR in frog and rabbit muscle but inhibited the rate of $Ca^{++}$ uptake. Furthermore, Weber (1968) concluded that at high adenosine triphosphate (ATP) concentrations caffeine decreases the coupling between ATP hydrolysis and $Ca^{++}$ inflow. Caffeine either inhibits flow without inhibition of ATP hydrolysis rate or stimulates ATPase activity without stimulating $Ca^{++}$ flow. At low ATP concentrations, caffeine inhibits the ATPase activity without affecting the rate of $Ca^{++}$ inflow (Weber, 1968). Therefore, caffeine has the potential to increase SR release of $Ca^{++}$ but may decrease the rate of $Ca^{++}$ uptake, resulting in exercise performance being affected.

# Caffeine Usage and Its Effects on Repeated-Sprint Performance

There has been a sufficient number of studies that have examined the effects of caffeine supplementation on aerobic performance, but few reviews have examined the effect solely on anaerobic performance. Moreover, the ergogenic effects of caffeine supplementation on repeated-sprint ability (RSA) and gender have been scarce.

Studies investigating caffeine supplementation on repeated-sprint performance have been equivocal. A recent meta-analysis conducted by Brown, Brown, and Foskett (2013) investigated the effects of caffeine on repeated-sprint performance in team-sport athletes. The researchers extracted eight studies that fit the criteria and found that caffeine did not have a significant effect on RSA in team-sport athletes. In this section, studies involving running, swimming, and cycling will be highlighted further.

## Running

Carr et al. (2008) investigated the effects of 6 $mg \cdot kg^{-1}$ caffeine ingestion on repeated-sprint running performance and reaction times in team-sport players. Carr et al. (2008) hypothesized that caffeine ingestion prior to exercise would result in faster running times, along with faster simple and choice reaction times (RT). Carr et al. (2008) found a significantly improved total individual set time for all five sets during caffeine ingestion, whereas no significant main effect for treatment for the fastest single sprint time for each set. Lastly, there was no significant main effect for treatment on simple reaction time and choice reaction time. The study promotes the idea that caffeine ingestion of 6 $mg \cdot kg^{-1}$ 60 min prior to exercise significantly improves repeated-sprint running ability, both in sets with 25 seconds and 60

seconds of recovery time. Additionally, the study concluded that post-exercise blood lactate concentration significantly increases with caffeine, depending on how long the recovery time between sprints lasts (Carr et al., 2008). Repeated-sprint ability increased in the caffeine trials due to the ergogenic effects. Blood lactate concentration was not significantly increased in sets with longer active recovery periods, possibly due to the lactate being efficiently cleared.

Similarly, Pontifex et al. (2010) investigated the effects of caffeine ingestion on repeated-sprint ability (RSA), reactive agility time (RAT), and sleep and next-day performance on male athletes. The researchers found that ingesting 6 $mg \cdot kg^{-1}$ of caffeine 1 hour before exercise significantly improved combined total time for each set and best sprint time performance but did not affect RAT performance (Pontifex et al., 2010). In another study, Del Coso et al. (2012) found that 3 $mg \cdot kg^{-1}$ displayed a significant improvement in a repeated protocol in 19 semi-professional soccer players. These two studies observed an ergogenic effect when ingesting caffeine prior to repeated-sprint activity and thus is in line with the findings of Carr et al. (2008).

Paton et al. (2001) examined the effects of caffeine ingestion on performance of a repeated-sprint test on team-sport athletes. The researchers hypothesized that caffeine would produce an enhancement of performance in a single 30-second sprint but increase greater fatigue with repeated sprints. The results revealed a 0.1% increase in mean time to complete the 10 sprints from placebo ingestion to caffeine ingestion. Furthermore, fatigue was evident as an increase in time of each sprint was displayed linearly over the 10 sprints. The increase in each sprint time revealed a 0.7% increase from the placebo trial to the caffeine trial, thereby observing a negligible effect on 6 $mg \cdot kg^{-1}$ of caffeine ingestion on repeated-sprint running ability and

fatigue (Paton, Hopkins, & Vollebregt, 2001). These findings conflict with Carr et al. (2008), Pontifex et al. (2010), and Del Coso et al. (2012).

Similarly, Ermolao et al. (2017) investigated the effect of carbohydrates (CHO) with caffeine (Caf); CHO plus (Arg); CHO plus branched-chain amino acids (BCAA); CHO plus Caf, Arg, and BCAA (ALL); and CHO only. Ermolao et al. (2017) hypothesized that ALL would lead to higher RSA performance than a single component or the placebo. The placebo consisted of a mixture of carbohydrate, vitamins, mineral salts, and flavorings; the amount of caffeine was 300 milligrams. Ermolao et al. (2017) concluded that adding Caf, Arg, and BCAA does not improve RSA in soccer players. In the trial with only caffeine and placebo, there was no significant difference in HR, OS, HL, AST, PP, TT, PP, and AP (Ermolao et al., 2017). Out of all the supplements, Ermolao et al. (2017) suggested that caffeine potentially had the most influence in improving RSA due to stimulation of the sympathetic nervous system. These findings are in line with Paton et al. (2001) but are conflicting with Carr et al. (2008), Del Coso et al. (2012), and Pontifex et al. (2010). The differences may lie between the recovery times between each sprint, the training statuses of the participants, and the amount of caffeine being administered.

## Swimming

Goods et al. (2017) investigated the effects of 3 $mg \cdot kg^{-1}$ of caffeine on repeated freestyle sprint performance and blood lactate concentration in elite male swimmers. Goods et al. (2017) hypothesized that 3 $mg \cdot kg^{-1}$ would increase improvement in the first sprint and mean sprint time. The researchers found that there was a significant effect for improved sprint time and blood lactate concentrations for the caffeine trial. Furthermore, there was no treatment effect for RPE and HR (Goods et al., 2017). This study is in line with the likes of Carr et al. (2008) due to both

studies stating that caffeine ingestion increases repeated-sprint ability. The current study used a smaller caffeine dose of 3 $mg \cdot kg^{-1}$ and still elicited an ergogenic effect, whereas Paton et al. (2001) did not see an ergogenic effect with 6 $mg \cdot kg^{-1}$ of caffeine. This may be due to the amount of time that is used for recovery between each individual sprint, along with the mode of exercise being tested.

## Cycling

Schneiker et al. (2006) investigated the effects of caffeine on prolonged intermittent-sprint ability in team-sport athletes and found that caffeine ingestion significantly enhances performance. Results indicated that caffeine significantly increased work performed during the sprints, peak power, and lactate concentration (Schneiker et al., 2006). These findings are in line with the likes of Carr et al. (2008) and Goods et al. (2017) signifying that caffeine ingestion results in increased repeated-sprint performance. This study provides insight on caffeine ingestion and the specificity of team-sport performance through simulation of a whole game using two 36-minute halves.

In a similar study, Paton et al. (2010) investigated the effects of caffeinated chewing gum, which contained 240 mg of caffeine, on fatigue and hormone response during repeated-sprint cycling performance in male competitive cyclists. The researchers concluded that fatigue significantly decreased during the caffeine trials in relation to the placebo trials. Furthermore, the delayed fatigue was associated with elevated testosterone levels and decreased cortisol levels in the caffeine trials (Paton et al., 2010). These studies are in line with Schneiker et al. (2006) and showed an ergogenic benefit at a lower dose.

In another study, Clarke et al. (2016) examined the effects of coffee and caffeine supplementation, which both contained 3 $mg \cdot kg^{-1}$ of caffeine, on repeated-sprint cycling performance in untrained males. The researchers found that there was no significant difference in caffeine ingestion on peak power output and mean power output. Furthermore, RPE was similar in all trials. Therefore, Clarke et al. (2016) concluded that coffee and caffeine ingestion of 3 $mg \cdot kg^{-1}$ did not improve repeated-sprint cycling performance in untrained males. This conflicts with Schneiker et al. (2006) and Paton et al. (2010) in regard to the effects of caffeine intake on repeated-sprint cycling performance.

## Gender Differences

The physiological differences in gender are imperative to study to understand how to maximize performance between the genders. Studies highlighting the gender differences of caffeine supplementation and repeated-sprint performance have been scarce. Therefore, this section will go in depth on the main physiological differences between genders, the differences in performance in repeated-sprints, and the differences in caffeine response between males and females.

### Physiological Differences

The physiological differences between males and females have been well documented. Aspects such as body composition and hormone release affect overall exercise and athletic performance. Males and females have unique physiologies that set the two apart from each other, thus affecting exercise results. The main factors that will be underlined in this section include body composition, hormones, enzymes, substrate utilization, and muscle fibers.

## Body Composition

The most visible differences when comparing the two sexes is body composition. On average, males are taller, heavier, have a greater lean mass, and have a lower fat mass in comparison to females at the same age (Mayhew & Salm, 1990). By having greater lean mass, males can produce a higher absolute muscle force and power output than females (Billaut & Bishop, 2009). Even with matching the exercise intensity percentage to the amount of body mass and lean body mass, males still result in better results than females (Billaut, Giacomoni, & Falgairette 2003). For example, Billaut et al. (2003) found that males remained more powerful than females when the data was conveyed relative to lean body mass and lower limb lean volume during 8-second sprints on a cycle ergometer. Therefore, there must be another reason, other than body composition, that leads to contrasting exercise results between males and females.

## Enzymes

Enzyme activity can provide an insight into the differences in metabolism between males and females. Borges and Essen-Gustavsson (1989) and Komi and Karlsson (1978) both found that activities of myosine adenosine triphosphatease (ATPase) and creatine phosphokinase were higher in males than females. These studies suggest that greater potential energy from the phosphagen system in males result in increased performance. Furthermore, glycogen phosphorylase, phosphofructokinase (PFK), and lactate dehydrogenase are more abundant in males than females (Billaut & Bishop, 2009). The increase in these glycolytic and glycogenolytic enzymes results in more energy being broken down for energy during anaerobic exercise, such as repeated-sprints (McArdle, Katch, & Katch, 2014). With more enzymes, such as ATPase, creatine phosphokinase, glycogen phosphorylase, PFK, and lactate dehydrogenase, there is more

potential for substrates being broken down for energy. The increase in energy being broken down can eventually lead to an increase in performance, thus showing performance differences between genders.

Substrate Utilization

Gender differences in metabolism has been investigated thoroughly. Studies have shown that the aerobic contribution is more important in females during prolonged sprints, submaximal exercises, and isometric contractions (Billaut & Bishop, 2009). Hill and Smith (1993) found that the aerobic contribution to total work during a 30-second cycle sprint was 20% in males and 25% in females. The greater reliance on anaerobic metabolism in males would result in increased blood lactate levels and a slower recovery but would result in a faster rate of ATP production in males (McArdle, Katch, & Katch, 2014).

Along with differences in anaerobic glycolysis utilization, the utilization of the phosphagen system must be investigated. Esbjörnsson-Liljedahl, Bodin, Jansson, and Smaller (2002) found that there was a smaller reduction in ATP in females than in males in Type II muscle fibers. This study compared ATP reduction in males and females after completing three Wingate tests with 20 minutes of recovery in between. Furthermore, Esbjörnsson-Liljedahl, Sundberg, Norman, and Jansson (1999) used the same protocol and found a similar ATP and PCr content decrease. These studies support the notion that substrate utilization differs between males and females, which can result in contrasting performance results.

## Muscle Fibers

Muscle fiber size and property differences between males and females may have an impact on peak power and the ability to maintain power output. It is generally accepted that females have smaller fiber cross-sectional area (CSA) in all fiber types than males. This is true when comparing an untrained female and an untrained male as well as elite-athlete females and their male counterparts (Billaut & Bishop, 2009). A smaller CSA may result in lower performance levels in comparison to a larger CSA. Along with a smaller CSA, females tend to have less distribution of Type IIx fibers and have a greater distribution of Type I fibers (Haff & Triplett, 2016). Since Type IIx muscle fibers are primarily utilized in anaerobic exercises, such as sprinting, less Type IIx fibers may result in a decrease in performance (Haff & Triplett, 2016; McArdle, Katch, & Katch, 2014). Therefore, muscle fiber size and type may play a role in the gender-specific disparities in anaerobic exercise performance.

## Hormones

The secretion of hormones, one may argue, is the most important factor that plays a role in the reason for differences in exercise performance. Since males have elevated testosterone levels than females, males can increase protein synthesis more, which leads to muscle hypertrophy (Ahtiainen, Pakarinen, Alen, Kraemer, & Häkkinen, 2003; McArdle, Katch, & Katch, 2014; Sinha-Hikim, Cornford, Gaytan, Lee, & Bhasin, 2006). Since males have an increased opportunity for muscle hypertrophy, males have the advantage of creating a larger CSA than women. Furthermore, females have elevated estrogen levels in comparison to males (Haff & Triplett, 2016). This results in increased growth hormone (GH) concentration, which stimulates lipolysis and reduces glycogenolytic activity by reducing plasma adrenaline secretion

(Nygaard, 1981; Ruby et al., 1997). The reduction in glycogenolytic activity and adrenaline secretion results in decreased sugar metabolism and performance in the anaerobic nature (McArdle, Katch, & Katch, 2014).

Additionally, females of similar fitness levels have lower plasma catecholamine levels during exercise at the same relative intensity (Billaut & Bishop, 2009). Catecholamines increase force production, increase muscle contraction rate, increase blood pressure, increase energy availability, increase muscle blood flow through vasodilation, and increase secretion rates of other hormones (Haff & Triplett, 2016). Therefore, the overall decrease in plasma catecholamine concentration present in females may affect exercise performance due to the roles of catecholamines.

## Anaerobic Performance

There have been studies that have investigated the differences in gender when it comes to repeated-sprint performance. Perez-Gomez et al. (2008) investigated the gender differences in muscle mass and aimed to explain the gender differences in running and cycling performance. Body composition through dual-energy X-ray absorptiometry (DEXA) running (30 and 300 m test) and cycling (Wingate test) sprint performance was assessed. The participants consisted of 123 males and 32 females who were studying physical education. All of the subjects' body composition was assessed through a DEXA and they performed the running and cycling tests. The main measurements taken were lower limb mass (LM), total lean mass (TM), peak power (PP), mean power (MP), and sprint running times. Perez-Gomez et al. (2008) concluded that there were no gender differences observed of the linear relation between LM and PP or MP. However, when MP was expressed per kg of LM, males achieved a 22% higher value.

Furthermore, the 30- and 300-meter running times divided by the relative lean mass of the lower extremities were significantly slower in females than males. These findings support the idea that males can physiologically outperform females in sprint performance.

In a similar study, Dorè et al. (2005) found that peak power output was significantly greater in males than females participating in a 2 x 5-8-second cycle ergometer sprint. Moreover, Vincent et al. (2004) investigated the gender differences in a 30-second Wingate test. The researchers observed a significantly greater peak power output and mean power output in males in comparison to females. Also, glucose and insulin were significantly greater in the female participants. The findings in Dorè et al. (2005) and Vincent et al. (2004) are in line with Perez-Gomez et al. (2008), stating that sprint performance is greater in males than in females.

When it comes to a repeated-sprint protocol and gender differences, this area has been poorly examined. One of the first studies to investigated repeated-sprint activity and gender differences was conducted by Brooks et al. (1990). The researchers conducted a repeated-sprint protocol that consisted of 6-second sprints on a non-motorized treadmill with 30 seconds of recovery in between sprints. Males produced a greater peak power and total work than females in this study. In another study, Bishop, Edge, Dawson, Goodman, & Preen (2003) found that males performed better than females during five 6-second cycle sprints every 30 seconds. The researchers observed a greater absolute and relative work in males along with a greater work decrement. Therefore, the limited literature available suggests that males experience greater absolute and greater work, along with greater fatigue. This may be due to greater involvement of anaerobic glycolysis, enzymic activity, differences in hormones, or even muscle fiber types.

## Caffeine Response

The literature highlighting the gender differences of caffeine response to repeated-sprint performance has been scarce. Furthermore, there have been very few studies that highlighted the differences in gender and the response to caffeine during a repeated-sprint running protocol. Astorino et al. (2012) investigated the effects of Red Bull energy drink, which has a caffeine content of 1.3 $mg \cdot kg^{-1}$ body weight, on repeated-sprint performance in women athletes. The findings indicated that 255 mL of Red Bull did not alter repeated-sprint performance, RPE, or HR in women athletes in comparison to placebo. This may be due to the amount of caffeine that is present in Red Bull energy drink. In another study, Paton, Costa, and Guglielmo (2014) found that caffeinated chewing gum (3-4 $mg \cdot kg^{-1}$ body weight) increased sprint power and mean power in male and female competitive cyclists. The researchers also indicated that there were large inter-individual variations with caffeine supplementation and apparent gender-related differences in sprint performance. Since the previous studies focused on the athletic population, further investigation must be done to examine the effects of caffeine supplementation on repeated-sprint performance in female non-athletes.

# CHAPTER 3

# METHODOLOGY

This research study was performed on three separate days by each participating subject. The first official visit consisted of health screening protocols, informed consent, instructional information, and anthropometric measurements. The second and third official visits consisted of the exercise intervention session, which was high-intensity interval training using a repeated-sprint-based protocol. During the second and third visits, the subjects alternated supplementing either caffeine or a placebo 1 hour prior to the sprinting protocol. The estimated total time spent with each subject was about 3-5 hours. All the sessions were conducted at Northern Illinois University's Kinesiology and Physical Education Department in Anderson Hall in the Graduate Assistant Office (AND123) and Gym B (AND102) or AND135.

## Participants

The study included 32 healthy, non-athlete students (Males: 17; Females: 15) with ages ranging from 19-28 years old. The participants who were recruited for this study were selected from the general student body of Northern Illinois University. The target demographic for this study were healthy, non-athlete college students. The criteria to be considered for inclusion of the study was the following: currently enrolled as a student of Northern Illinois University, did not take medications that may have posed a health risk, and did not have a medical condition or injury that may have put the individual at risk during testing. The way students were recruited

for this study was by posting flyers throughout academic buildings, word of mouth, and recruitment sessions during lecture classes with permission from the instructor along with a sign-up sheet. Students currently enrolled in a class related to kinesiology and physical education received extra credit for that class as an incentive for participating in the study. Communication with the class instructor was needed before officially handing out said extra credit.

All participants underwent a health screening procedure, which included completion of a Health History Questionnaire. This helped identify any heart-related conditions, such as hypertension and coronary heart disease. Individuals who were considered non-hypertensive, had no risk factors for coronary heart disease, no cardiopulmonary conditions, took no medications that have adverse effects with caffeine supplementation, and no previous skeletal injuries were included in the study. Participants who were pregnant were immediately excluded from the study. Furthermore, participants answered a caffeine usage questionnaire to determine if their current caffeine use was appropriate to be included in the study. If the current caffeine use did not align with the inclusion criteria of the study, participants still participated if abstinence of caffeine was practiced for two weeks prior to the exercise trials. Additionally, subjects completed a Blood Health/Finger Prick Blood Analysis Questionnaire and any subject who answered “yes” was excluded from the study to prevent spread of blood-borne pathogens.

Since this study followed a crossover design, each subject supplemented caffeine during one session and supplemented a placebo in the other. The two trials were categorized into a caffeine trial (CAF) and a placebo trial (PLA). The two trials were conducted at least seven days apart. Determination of which trial was scheduled first with each subject was through a randomization method. This method was conducted following the completion of the first

meeting, in which the subject was cleared to participate in the study and then scheduled to start off in either the caffeine or placebo trial.

## Pre-exercise Supplementation

Caffeine or placebo was supplemented to each participating individual at least 45 minutes prior to starting the exercise session. During the caffeine trial, 200 milligrams of pure caffeine capsules were given. During the control trial, a placebo pill was ingested instead of the caffeine pills. The placebo consisted of 200 mg of microcrystalline cellulose in capsule form. This study followed a randomized double-blind crossover design, where neither the participant nor researcher was aware of which supplement was being ingested before each trial.

## Preliminary Procedures

After contact of an interested individual, a set day and time was given to meet for the first visit. This first visit consisted of a health screening to determine eligibility for the study. The meeting occurred in the Graduate Assistant Office in Anderson Hall at Northern Illinois University. The health screening consisted of completing the Informed Consent, Inclusion Form, Healthy History Questionnaire, Caffeine Usage Questionnaire, Blood Health/Finger Prick Blood Analysis Questionnaire, anthropometric measures, and blood pressure. The anthropometric measures consisted of measuring height and weight using a standard scale. With the measured height and weight, the body mass index (BMI) was also calculated. Blood pressure was taken in a seated position in a low-noise environment using a stethoscope and sphygmomanometer. If the first blood pressure read above 140 systolic and/or 90 diastolic, a second measurement was taken 5 minutes after to determine if the individual had hypertension. If the participant's final recorded

blood pressure was over 140 systolic and/or diastolic, that participant was excluded from the study. After it was determined whether the participant could be included in the study, the participant scheduled two exercise sessions one week apart from each other. This first exercise trial occurred at least three days from the preliminary session. If the participant was considered a heavy caffeine user, there was a two-week wash-out period between the preliminary session and the first exercise session. After scheduling the two exercise sessions, the researcher conducted a familiarization trial with the participant. This familiarization trial consisted of one set of 6 x 30-meter sprint at a comfortable pace. This was in place to familiarize the participant for the upcoming exercise sessions. After familiarization of the exercise trial, the preliminary session was concluded.

## Exercise Sessions

The second and third visits consisted of the repeated-sprint running protocol with pre-exercise supplementation of either caffeine or placebo. If the participant exceeded the recommended amount of daily caffeine intake for the caffeine usage questionnaire, the participant was asked to refrain from caffeine for two weeks. The participants who did not exceed the recommended amount were asked to sustain their normal dietary habits and to refrain from ingesting any caffeine 48 hours prior to their testing time. Additionally, participants were asked to refrain from intense physical activity for 24 hours prior to exercise testing. On testing days, the participant was asked to abstain from food and fluids (except water) 1 hour prior to arriving to the laboratory to ingest either the caffeine or placebo pill. The participants were required to arrive 1 hour prior to their scheduled exercise trial to ingest either 200 milligrams of caffeine or placebo. The caffeine or placebo pill was ingested in front of a research assistant

along with 200 mL of water. Before ingestion, blood pressure (BP) was taken by the researcher. The participant had the option to leave the vicinity to attend class in the building but could not leave Anderson Hall. Additionally, the participant was instructed to not ingest any food or liquids (except water) during the wait period. It was imperative for the participant not to engage in physical activity or intake any food during that time.

Once 45 minutes had passed after ingestion of either caffeine or placebo, the participant met back with the researcher to start the exercise protocol. Before starting the repeated-sprint protocol resting blood lactate (BLC), resting heart rate (HR), rating of perceived exertion (RPE) using the Borg scale, and blood pressure were measured. BLC was measured by a Nova Biomedical Lactate Plus lactate meter (Nova Biomedical, Waltham, MA). HR throughout the exercise session was measured by a Polar heart rate monitor (Polar Electro Inc., Lake Success, NY). Each participant was fitted to appropriate H7 strap size and hooked up to the sensor located directly below the xiypoid process. The corresponding watch was sized onto the participant's wrist (participant's choice). Instructions for the exercise was given to the participant as well as telling the participant that if felt uneasy, the test would be ceased. Once preparatory and baseline measurements were completed, the participant performed a warm-up consisting of 3 minutes of a light jog (>50% of maximum heart rate) followed by 3 minutes of dynamic stretches. The dynamic stretches were chosen by the participant and, if needed, the researcher helped assist the participant.

For this study, each participant performed three sets of 6 x 30-meter sprints with 20 seconds of active recovery between the sprints. The measurements that were taken during the exercise protocol included BLC, HR, RPE, single sprint time (SS), and total sprint time for each

set (TS). Following each of the sprint sets, data was collected and an active recovery phase lasting 5 minutes took place (total of two recovery phases).

The floor was marked with floor tape from the start/finish line to another tape marker that was 15 meters (49.21 ft.) apart. Once the participant was warmed up and the instructions were given, the participant was then lined up at the start/finish line. On the researcher's command, the participant sprinted down to the second marker and sprinted back to the finish line after touching the second tape marker with his/her hand. One "all-out sprint" down to the second marker and back to the start/finish line equated to 30 meters. The participant completed a total of six 30-meter sprints with 20 seconds of recovery in between the sprints. The type of recovery that was used was an active recovery method, which involved the participant actively walking around at a slow pace before reporting back to the start/finish line. Single sprint time was recorded from the beginning of the sprint until the point at which the subject crossed the start/finish line using a handheld standard stop-watch. After each sprint, the researcher recorded the sprint time during the 20-second recovery period. This process was completed six times, which completed one set. After the sixth and final sprint of the set was completed, the participant was advised to immediately walk to the blood collection station, approximately 10-15 feet from the start/finish line. Once the participate was seated, data was collected in this respective order: HR, RPE, and BLC. BLC was taken on the participant's right hand. Directly following the data collection, the recovery time began. The recovery period consisted of 5 minutes of active recovery, where the participant was advised to walk at a comfortable pace. At the end of the 5-minute recovery period, the subject situated him or hersel back to the start/finish line to begin the next set of sprints until the last set was completed.

The cool-down consisted of 5-10 minutes of a slow walk until the subject's HR fell below 50% of the age-predicted max HR. After walking, the participant was allowed 5 minutes of static stretching of the lower body. Once the participant completed the cool-down period and was noticeably able to continue with daily activities, the participant could leave. The participant was advised to contact the researcher if any issues were to arise following the exercise session. Once all the data was collected and the participant was dismissed, the data was inputted into an Excel spreadsheet on the researcher's computer. The hardcopy of the two exercise sessions was stored in the participant's folder and was locked away in a cabinet for future reference.

## Statistical Analysis

Demographic, anthropometric, independent variables, and dependent variables were recorded in Excel (Microsoft Corporation, Redmond, WA). The data was then transferred and analyzed using SPSS Statistics 23 (SPSS, Inc., Chicago, IL). The results of each independent variable were analyzed by a two-way repeated-measures ANOVA to determine any significant interactions or main effects. Further, a follow-up paired-samples *t* test was used. The alpha level for significance was set at $p < 0.05$ for all tests.

CHAPTER 4

# RESULTS

## Subject Characteristics

Thirty-five students from Northern Illinois University's student population volunteered to participate in the study; only 32 students completed the study. Descriptive statistics for all subjects are provided in Table 1. One of the 35 participants was unable to complete the entire exercise protocol due to feeling uneasy after the first sprint set, resulting in not completing the second and third sprint sets. The remaining two subjects were unable to attend the exercise sessions. Therefore, these three subjects were excluded from the data set.

Table 1: Descriptive Characteristics of Subjects (mean ± SD)

| **Descriptive Characteristics of Subjects** | | | | |
|---|---|---|---|---|
| | Age (yrs) | Height (cm) | Weight (kg) | BMI ($kg/m^2$) |
| All (N=32) | 22.19 ± 2.29 | 170.58 ± 10.18 | 74.78 ± 12.76 | 25.59 ± 2.78 |
| Males (N=17) | 22.35 ± 2.98 | 176.60 ± 9.25 | 82.12 ± 12.18 | 26.21 ± 2.12 |
| Females (N=15) | 22.00 ± 1.20 | 163.75 ± 6.14 | 66.47 ± 7.17 | 24.88 ± 3.31 |

## Blood Pressure

The results of the two-way repeated-measures ANOVA for systolic blood pressure indicated there was no significant interaction [$F(1,31) = 2.107$, $p = 0.157$], but there were main effects for condition [$F(1,31) = 6.526$, $p = 0.016$] and time [$F(1,31) = 6.102$, $p = 0.019$]. Follow-up paired-samples *t* tests indicated that the caffeine condition resulted in significant ($p = 0.017$) increases in systolic blood pressure from pre- to post-supplementation, but there was no change ($p = 0.530$) for the placebo condition (Table 2). For diastolic blood pressure, there was a significant Condition x Time interaction [$F(1,31) = 4.285$, $p = 0.047$]. The follow-up paired-samples *t* tests indicated that the caffeine condition resulted in significant ($p = 0.025$) increases in diastolic blood pressure from pre- to post-supplementation, but there was no change ($p = 0.925$) for the placebo condition (Table 2).

Table 2: Pre-supplementation vs Post-supplmentation SBP and DBP (mean ± SD)

| **Results: Pre-Supplementation vs Post-Supplmentation SBP and DBP** | | | | |
|---|---|---|---|---|
| Condition | Pre-SBP (mmHg) | Post-SBP (mmHg) | Pre-DBP (mmHg) | Post DBP (mmHg) |
| Caffeine | 124 ± 6 | 127 ± 6 * | 78 ± 10 | 82 ± 5 * |
| Placebo | 123 ± 6 | 124 ± 7 | 79 ± 4 | 79 ± 5 |

*significant change ($p<0.05$)

## Heart Rate

There was a significant two-way (Condition x Time) interaction for heart rate [F(3,93) = 3.368, p = 0.022], but the follow-up paired-sample *t* tests indicated there were no significant mean differences between the caffeine condition and placebo at any of the time points (Figure 1).

## Blood Lactate Concentration

The two-way repeated-measures ANOVA resulted in a significant Condition x Time interaction [$F(3,93) = 18.950$, $p < 0.001$] for blood lactate. The follow-up paired-samples *t* tests indicated that the caffeine condition resulted in significantly greater blood lactate values than the placebo condition after each sprint set, but not at rest (Figure 2).

## Rating of Perceived Exertion

For RPE, there was no significant Condition x Time interaction [$F(3,93) = 1.602$, $p = 0.194$] or main effect for condition [$F(1,31) = 4.090$, $p = 0.052$], but there was a main effect for time [$F(3,93) = 292.810$, $p < 0.001$] (Figure 3).

## Average Sprint Time

There was no significant Condition x Time interaction [$F(2,62) = 1.766$, $p = 0.179$], but there were significant main effects for Condition [$F(1,31) = 36.839$, $p < 0.001$] and Time [$F(2,62) = 5.806$, $p = 0.006$]. Follow-up paired-samples *t* tests indicated that the caffeine condition resulted in significantly faster sprint times during all three sprint sets compared to the placebo condition (Figure 4).

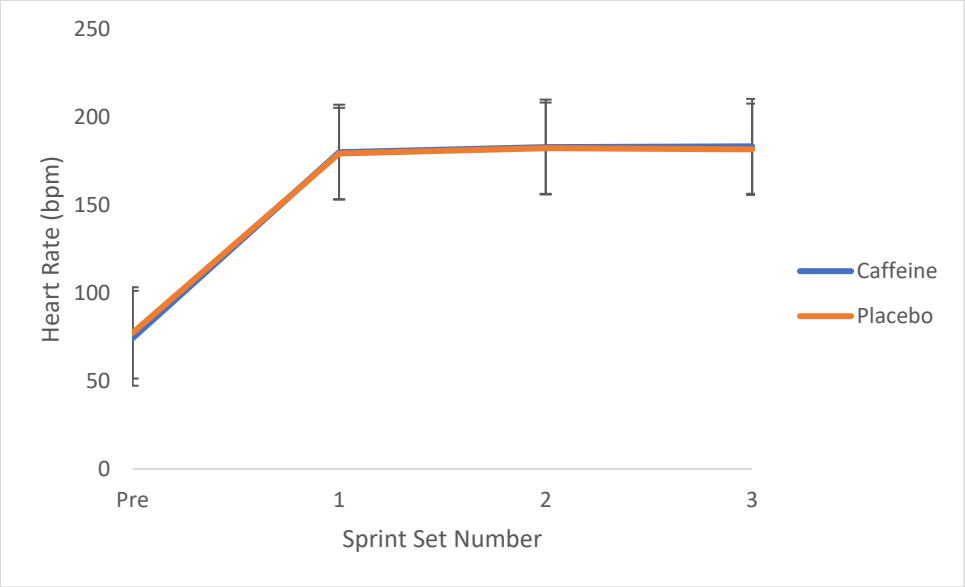


**Figure 1.** Means for heart rate between caffeine and placebo during repeated-sprint sets. The results show that there is no significant difference in heart rate between the caffeine and placebo trials.

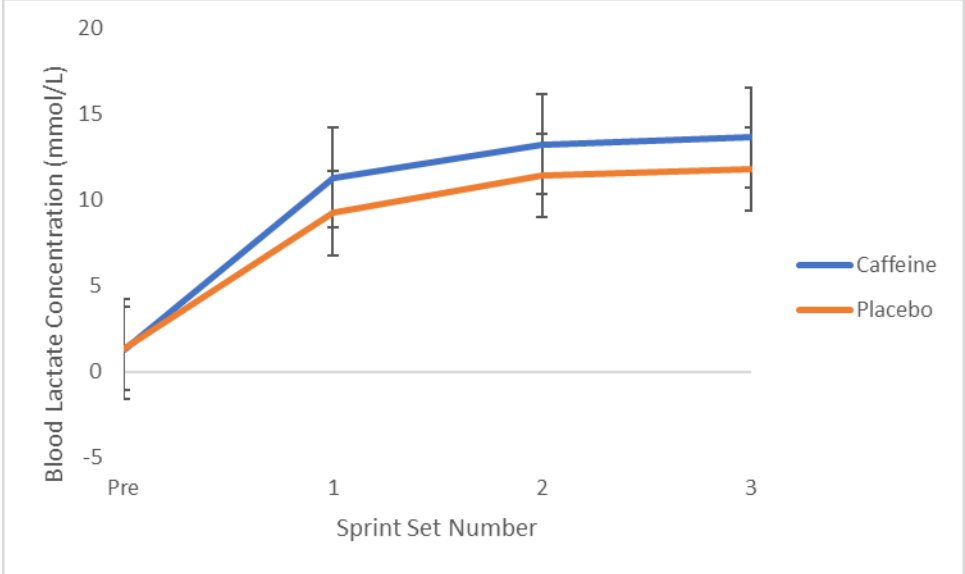


**Figure 2.** Means for blood lactate concentration between caffeine and placebo during repeated-sprint sets. The results show that there is a significant increase in BLC in the caffeine trial, in comparison to the placebo trial.

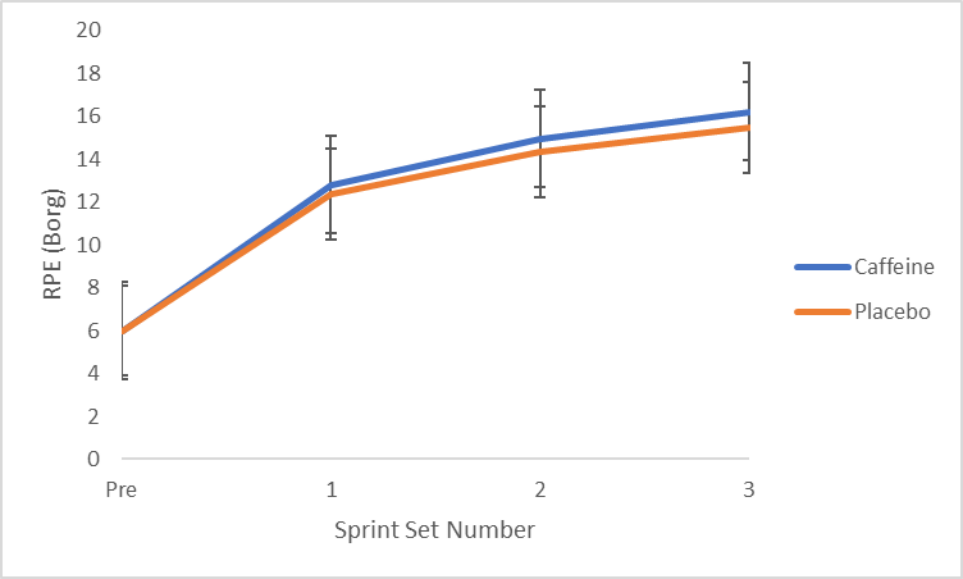


**Figure 3.** Means for rating of perceived exertion between caffeine and placebo during repeated-sprint sets. The results show that there is no significant difference in RPE between the caffeine and placebo trials at pre-exercise, after sprint set 1, and after sprint set 2. However, there is a significant increase in RPE during sprint set 3 in the caffeine trial, in comparison to the placebo trial.

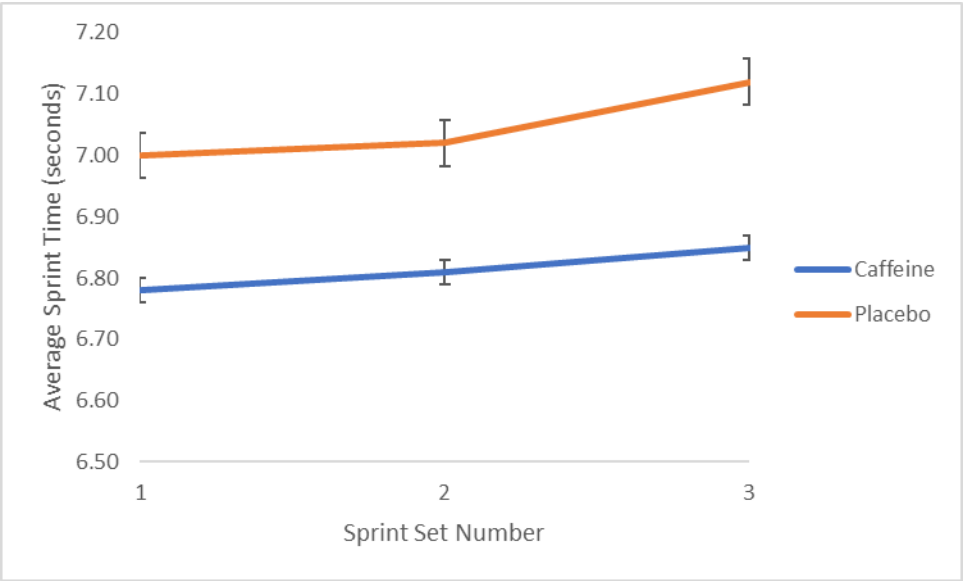


**Figure 4.** Means for average sprint time between caffeine and placebo during repeated-sprint sets. The results show that there is a significant decrease in average sprint time in the caffeine trial, in comparison to the placebo trial.

# CHAPTER 5

# DISCUSSION

The purpose of this study was to examine the effects of 200 mg of caffeine on repeated-sprint performance in college-age non-athletes. The assumption was that 200 mg of caffeine would result in an ergogenic effect during repeated-sprints. Along with resulting in decreased sprint time, it was assumed that caffeine would also result in an increase in blood lactate concentration. Additionally, it was hypothesized that caffeine would increase heart rate and decrease the rating of perceived exertion.

## Blood Pressure

In the current study, both systolic and diastolic blood pressure had a significant increase after 45 minutes of caffeine ingestion. This finding is in line with the literature that suggests that caffeine results in acute increases in blood pressure (Casiglia et al., 1992; Lane & Williams, 1985). According to James (2004), acute elevations in blood pressure from 5 to 15 mmHg systolic and 5 to 10 mmHg diastolic are representative in doses equivalent to those consumed in everyday life. It is important to note that the mean pre-supplementation systolic blood pressure was abnormally high in the caffeine and placebo trials. A possible explanation may be the increased anxiety of the subjects due to feelings of nervousness prior to the exercise session. Nonetheless, the findings in this study add to the literature and suggest that caffeine supplementation acutely increases systolic and diastolic blood pressure.

## Heart Rate

The heart rate values between caffeine and placebo were insignificant in this study. This finding is in line with Goods et al. (2017) but challenges Glaister et al. (2008). Goods et al. (2017) found that mean heart rate during a swimming repeated-sprint protocol was insignificant between the caffeine and placebo trials. Glaister et al. (2008) reported a significantly higher heart rate in the caffeine trial than the placebo trial while measuring multiple sprint running performance. Some possible factors that may have played a role in the study by Goods et al. (2017) are that the subjects were highly trained male athletes. Further, the amount of caffeine was at a relative value of 3 mg/kg $^{-1}$. Glaister et al. (2008) studied subjects who were considered average fitness level and used a relative dosage of 5 mg/kg $^{-1}$. In the current study, an absolute dose of 200 mg of caffeine was used. It may be possible that a higher dosage results in an increase in heart rate during repeated sprints, suggesting a dose-response relationship.

## Blood Lactate Concentration

Regarding blood lactate concentration, the current study produced significant results. This is in line with Bell et al. (2001), Carr et al. (2008), Collomp et al. (1992), Goods et al. (2017), and Schneiker et al. (2006) but challenges Cakir-Atabek (2017) and Greer et al. (1998). The data set indicated that caffeine resulted in significantly greater blood lactate than the placebo condition after each sprint (see Figure 2). Similar differences in blood lactate at rest was not displayed between the caffeine and placebo trials.

During the caffeine trial, the mean blood lactate values after sets 1, 2, and 3 were 11.32 mmol/L, 13.26 mmol/L, and 13.67 mmol/L, respectively, whereas the mean blood lactate values

during the placebo trial after the three sets were 9.24 mmol/L, 11,46 mmol/L, and 11.83 mmol/L, respectively. Further, the resting blood lactate values were at a mean of 1.30 mmol/L for the caffeine trial and at 1.37 mmol/L for the placebo trial. This study supports the notion that repeated-sprint activity results in significant increases in blood lactate concentration while further increasing the concentration with caffeine supplementation.

There have been studies that displayed higher blood lactate concentration with caffeine supplementation, but also studies that did not show a significance. Carr et al. (2008) displayed a significant increase in blood lactate concentration during a repeated-sprint exercise protocol with caffeine ingestion. Further, Goods et al. (2017) displayed an increase in blood lactate concentration after repeated freestyle sprints in elite male swimmers. On the contrary, Greer et al. (1998) displayed no effect of treatment between caffeine and placebo during repeated Wingate tests. The current study draws parallels to Carr et al. (2008) since both studies investigated caffeine's effect on repeated-sprint running performance.

The caffeine trial showed a greater increase in blood lactate after each sprint, possibly due to the inhibition of adenosine. Adenosine, which has been shown to increase pain perception, may have been inhibited by caffeine and resulted in a higher sustained utilization of Type 2 muscle fibers and resulted in a higher blood lactate concentration (Davis & Green, 2009). Increased concentrations of hydrogen ions, due to high utilization of anaerobic glycolysis, suggest that caffeine supplementation increased the energy contribution from the glycolytic system (Tomlin & Wenger, 2001). The increased blood lactate concentrations displayed in this study may suggest that caffeine can sustain anaerobic processes for a longer period of time,

perhaps due to adenosine inhibition or central nervous system stimulation. Further investigation is required to fully examine the mechanisms that play a role in this process.

## Rating of Perceived Exertion

It would seem logical that caffeine could potentially decrease the rating of perceived exertion due to its inhibitory effect on adenosine, thus possibly allowing individuals to exercise at a greater intensity or prolong the duration of activity (Davis & Green, 2009). In this study RPE significantly increased in the caffeine trial only after the last sprint set. As for pre-exercise and after sprints 1 and 2, RPE was not significantly different between the caffeine and placebo trials. These findings are in line with the literature focusing on caffeine supplementation on repeated-sprint performance (Goods et al., 2008; Schneiker et al., 2006). Further, it is line with Doherty and Smith's (2005) meta-analysis that investigated various caffeine-related studies and reported no difference in RPE between caffeine and placebo.

The current study suggests that caffeine resulted in no significant change in RPE, except in the last sprint set, but significantly increased sprint performance. Goods et al. (2008) and Schneiker et al. (2006) also reported similar findings in their repeated-sprint research. These findings propose that caffeine can aid in accomplishing more work despite the same perceived exertion. This can offer preliminary evidence that caffeine can increase high-intensity exercise performance without significant increases in perceived exertion.

## Average Sprint Time

There was no significant Condition x Time interaction, but there were significant main effects for Condition and Time. The average sprint time for each set, which consisted of six 30-

meter sprints, was significantly decreased with caffeine ingestion 45 minutes prior to the sprint protocol. These findings are in line with Carr et al. (2008), who concluded that 6 mg·kg-1 of caffeine 60 minutes prior significantly improved sprint running performance in team-sport athletes. Similarly, Pontifex et al. (2010) determined that 6 mg·kg-1of caffeine 60 minutes prior to repeated-sprint activity resulted in significantly lower combined total time for each set and best sprint time performance in male athletes. Further, Del Coso et al. (2012) found that 3 mg·kg-1 displayed a significant improvement in a repeated-sprint protocol in semi-professional soccer players. Similar improvements in spint time, possibly due to caffeine ingestion, are also displayed in Goods et al. (2017), Paton et al. (2010), and Schneiker et al. (2006).

There are some studies in the literature that are not in line with the findings of the current study. Paton et al. (2001) found a negligible ergogenic effect on 6 mg·kg-1 of caffeine on repeated-sprint running ability in team-sport athletes. Further, Ermolao et al. (2017) displayed no significant difference in repeated-sprint activity between the caffeine and placebo trials in trained team-sport athletes. Similarly, Clarke et al. (2016) fond no improvement in repeated cycling performance with 3 mg·kg-1 of caffeine ingestion in untrained males.

The current study found that caffeine ingestion prior to a repeated-sprint protocol resulted in lower average sprint times. A possible explanation, as stated prior, is the inhibition of adenosine. Increased arousal, through central nervous system stimulation, and decreased pain perception at a higher intensity are possible explanations for a decrease in average sprint times. A factor that must be taken into account is the dosage of the caffeine and the wash-out period. Most of these studies used a relative dosage, whereas the current study used an absolute dosage. Further, the current study followed a methodology where the subjects abstained from any

caffeine usage two weeks prior to the first session, whereas some studies in the literature only required a seven-day washout. These two factors possibly may have played a role in the results found in the current study. Further investigation is needed to highlight the mechanisms of caffeine on repeated-sprint performance.

## Implications

This study provided evidence that supplementing an absolute dosage of 200 mg of caffeine prior to training displayed an ergogenic effect on sprint performance in college-aged non-athletes. Since caffeine is one of the most widely used supplements, it is imperative to understand how it benefits the average individual during high-intensity exercise (Astorino & Roberson, 2010). Additionally, high-intensity interval training has gained popularity and it is vital to further examine its acute effects along with caffeine. The findings in this study can help further recognize the effects of caffeine and be conveyed to non-athletes in order to safely and effectively supplement caffeine.

## Limitations

There were a few limitations in this study. The first is that the caffeine dosage was an absolute value and not relative. Relative dosages consider body size, whereas absolute dosage is a set number. This may affect the observed ergogenic effect of caffeine due to varying body size of the subjects. Also, research assistants helped throughout the study. Presence of the research assistants during the sprinting protocol may have increased or decreased the arousal of the participants. Another limitation is the honesty of the participant. It may be possible that a subject may have ingested caffeine during the wash-out period, which could affect the study results.

Finally, the surface where the sprinting protocol took place was variable. It was observable that some of the participants had trouble decelerating, whereas other participants had no problem at all.

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# APPENDIX A

# RECRUITMENT MATERIALS

NORTHERN ILLINOIS UNIVERSITY
Department of Kinesiology and Physical Education
College of Education

STU INV & LEAD DEV
MAY15 2018 11669
VOID AFTER POSTER LOG#

# DEPARTMENT OF KINESIOLOGY AND PHYSICAL EDUCATION
# NORTHERN ILLINOIS UNIVERSITY

PARTICIPANTS NEEDED TO STUDY THE

**THE EFFECTS OF ACUTE CAFFEINE SUPPLEMENTATION ON REPEATED SPRINT PERFORMANCE IN COLLEGE-AGED NON-ATHLETES**

STUDY WILL INVESTIGATE CAFFEINE'S EFFECT ON:

***REPEATED SPRINT TIME***

***LACTIC ACID BUILD-UP DURING SPRINTING***

***PHYSIOLOGICAL DIFFERENCES BETWEEN MALES AND FEMALES***

ARE YOU AN NIU STUDENT BETWEEN THE AGES 18-30?

ARE YOU HEALTHY?

ARE YOU A NON-ATHLETE?

**IF SO, CONTACT MICHAEL BELBIS**

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# Recruitment Script

Hello, my name is Michael Belbis and I am a second-year graduate student here at Northern Illinois University studying exercise physiology. I am here today to speak about a research study that I am conducting, as part of my thesis project. This study will investigate the effect of caffeine supplementation on repeated-sprint performance while highlighting the differences in gender. To be included in this study, individuals must pass an inclusion criteria based on health history and caffeine dependency. Also, to be included in this study, individuals must range from 18-30 years old, be enrolled at NIU as a student, and must not be an NIU athlete. This research study will consist of three sessions. The first session is a preliminary session where health history, anthropometric measures, and other baseline measures will be assessed. The second and third session will consist of pre-exercise supplementation of either caffeine or placebo before participating in a repeated-sprint protocol. This protocol will consist of 3 sets of 6 x 30-meter sprints with 20 seconds of recovery in between sprints. Also, the participant will be assessed by their sprint times, blood lactate levels, heart rate, and rating of perceived exertion. These sprint exercises will be done in the blue court, Anderson 100. The total amount of time spent in this study will range from 3 to 5 hours, depending on the individual. This is a great opportunity to get involved in exercise science research, as well as understanding your physical capabilities. Also, you may receive extra credit for this class if you decide to participate. If you are interested please e-mail me at z1647603@students.niu.edu or stop by my office in Anderson 123. Also, I will leave this sheet on this desk. If you are interested, please print your name and z-id and I will contact you from there. Are there any questions for me? Thank you for your time and please contact me for any further information.

# APPENDIX B

# PRESCREEING FORMS

# Health History Questionnaire

Please answer the following questions to the best of your ability. For the following questions, unless otherwise indicated, circle the single best choice for each question. As is customary, all of your responses are completely confidential and may only be used in group summaries and/or reports. All information collected is subject to the Privacy Act of 1974. If you have any physical handicaps or limitations that would require special assistance with this questionnaire, please let your trainer know. This form is in accordance with the American College of Sports Medicine guidelines for risk stratification when followed correctly by your trainer. Your trainer should be certified with a national organization in order to use these forms correctly.

Name:_____ Ht.:_____ Wt.:_____

Gender:_____ Age:_____ Birthdate:_____

Address: _____

City:_____ State:_____ ZIP:_____ Phone:_____

Emergency Contact:_____ Phone: _____

Personal Physician:_____ Phone:_____

E-mail:_____

1. Have you ever had a definite or suspected heart attack or stroke? .....Yes No

2. Have you ever had coronary bypass surgery or any other type of heart surgery? .....Yes No

3. Do you have any other cardiovascular or pulmonary (lung) disease
   (***other than*** asthma, allergies, or mitral valve prolapse)? .....Yes No

4. Do you have a history of: diabetes, thyroid, kidney, liver disease. .....Yes No
   **(circle all that apply)**

5. Have you ever been told by a health professional that you have had
   an abnormal resting or exercise (treadmill) electrocardiogram (EKG)? .....Yes No

6. If you answered YES to any of Questions 1 through 5, please describe:

_____

_____

_____

_____

7. Do you currently have any of the following:
   a. pain or discomfort in the chest or surrounding areas that occurs when you engage in physical activity? ..... Yes No
   b. shortness of breath ..... Yes No
   c. unexplained dizziness or fainting ..... Yes No
   d. difficulty breathing at night except in upright position ..... Yes No
   e. swelling of the ankles (recurrent and unrelated to injury) ..... Yes No
   f. heart palpitations (irregularity or racing of the heart on more than one occasion) ..... Yes No
   g. pain in the legs that causes you to stop walking (claudication) ..... Yes No
   h. known heart murmur ..... Yes No

   Have you discussed any of the above with your personal physician? ..... Yes No

8. Are you pregnant or is it likely that you could be pregnant at this time? ..... Yes No
   If yes, what is your expected due date?_____

9. Have you had surgery or been diagnosed with any disease in the past 3 months? ..... Yes No
   If yes, please list date_____ and surgery/disease_____

10. Have you had high blood cholesterol or abnormal lipids within the past 12 months or are you taking medication to control your lipids? ..... Yes No

11. Do you currently smoke cigarettes or have quit within the past 6 months? ..... Yes No

12. Have your father or brother(s) had heart disease prior to age 55 OR mother or sister(s) had heart disease prior to age 65? ..... Yes No

13. Within the past 12 months, has a health professional told you that you have high blood pressure (systolic $\geq$ 140 OR diastolic $\geq$ 90)? ..... Yes No

14. Currently, do you have high blood pressure or within the past 12 months, have you taken any medicines to control your blood pressure? ..... Yes No

15. Have you ever been told by a health professional that you have a fasting blood glucose greater than or equal to 110 mg/dl? ..... Yes No

16. Describe your regular physical activity or exercise program:
    type:_____
    frequency: _____ days per week
    duration: _____ minutes
    intensity: *low* *moderate* *high* **(circle one)**
    BMI: _____

17. If you have answered YES to any of questions 7-16, please describe:

_____

_____

_____




P04-020

18. Are you currently under any treatment for any blood clots? ..... Yes No

19. Do you have problems with bones, joints, or muscles that may be aggravated with exercise? ..... Yes No

20. Do you have any back/neck problems? ..... Yes No

21 Have you been told by a health professional that you should not exercise? ..... Yes No

22. Are you currently being treated for any other medical condition by a physician? ..... Yes No

23. Are there any other conditions (mitral valve prolapse, epilepsy, history of rheumatic fever, asthma, cancer, anemia, hepatitis, etc.) that may ***hinder*** your ability to exercise? ..... Yes No

24. During the past six months, have you experienced any ***unexplained*** weight loss or gain (greater than ten pounds for no known reason)? ..... Yes No

25. If you have answered YES to any of questions 18-24, please describe:

_____

_____

_____

26. Please list below all prescription and over-the-counter medications you are currently taking:

| Medicine: | Reason for taking: | Dosage: | Amount/Frequency: |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

27. Are there any medicines that your physician has prescribed to you in the past 12 months which you are currently not taking? ..... Yes No
If so, please list:

_____

_____

_____

I have answered the Health History Questionnaire questions accurately and completely. I understand that my medical history is a very important factor in the development of my fitness/wellness program. I understand that certain medical or physical conditions which are known to me, but that I do not disclose to my trainer, may result in serious injury to me. If any of the above conditions change, I will immediately inform my trainer of those changes. I, knowingly and willingly, assume all risks of injury resulting from my failure to disclose accurate, complete, and updated information in accordance with the attached questionnaire. I also understand that in order to properly risk stratify my Health History Questionnaire, my trainer should have a minimum of a national certification as a personal trainer. My trainer also verbally explained this statement to me to my understanding.

Client's Signature:_____ Date:_____

Trainer's Signature:_____ Date:_____

## For Use by the Personal Trainer ONLY

Check the identified ACSM major coronary risk factors below:

_____ Lipids (TCH ≥ 200 OR HDL < 35)
_____ Family History
_____ Diabetes/glucose ≥ 110 mg/dl
_____ BMI ≥ 30
_____ Metabolic Disease
_____ Signs or Symptoms of Cardiovascular Disease_____
_____ Cardiovascular Disease_____
_____ Cigarette Smoking (or quit within the past 6 months)
_____ High Blood Pressure/Blood Pressure Medications
_____ Sedentary
_____ Pregnancy
_____ Respiratory Disease (asthma, emphysema, chronic bronchitis)

| Risk Stratification | Factors |
|---|---|
| _____ Apparently Healthy | One or No Risk Factors (No medical clearance required) |
| _____ Apparently Healthy Male ≥ 45; Female ≥ 55 | One or No Risk Factors (Initial medical clearance required) |
| _____ High Risk, No Signs or Symptoms | Two or More Risk Factors (medical clearance required) |
| _____ High Risk, with Signs and Symptoms | One or More Signs/Symptoms With or Without Risks (medical clearance required) |
| _____ Known Disease | Diagnosed Cardiopulmonary/Metabolic Disease (annual medical clearance required) |
| _____ Pregnancy | Medical Clearance Required |

***All clients needing written medical clearance from their personal physician must give it to their trainer prior to beginning their exercise program.***

Additional Comments: _____





**Health History Questionnaire** follows the American College of Sports Medicine recommendations for risk stratification. This must be performed on all clients in order to determine the need for medical clearance and/or exercise modifications. Any trainer or those making exercise recommendations should be certified in the proper use of the risk stratification process through a national organization.

If a client has a YES response to anything on page 1, he/she has KNOWN DISEASE, and must have medical clearance prior to beginning exercise.

If he/she has a YES response to anything on #7 a-h on page 2, your client is HIGH RISK WITH SIGNS/SYMPTOMS and must have medical clearance prior to exercise. If your client has a YES response to questions # 8 or 9, he/she must have medical clearance.

YES responses to two or more on questions 10-16 on page 2, your client is HIGH RISK WITHOUT SIGNS OR SYMPTOMS and must have medical clearance (unless he/she also has a YES answer in question #7 making them still HIGH RISK WITH SIGNS/SYMPTOMS).

All other questions on page 3 are at your own discretion. Remember, **when in doubt, refer out.** Please also refer to the most recent edition of *ACSM's Guidelines for Exercise Testing and Prescription* (Williams & Wilkins) as well as the most recent edition of the *ACE Personal Trainer Manual* (American Council on Exercise) for more explanations on the risk stratification. It is your responsibility as a trainer to remain updated on all changes or modifications for risk stratification in determining the need for medical clearance and exercise modifications/recommendations.



Premier Performance, Inc.
1457 Cambridge Common
Decatur, Georgia 30033
404-406-2873
pperform@bellsouth.net

American Council on Exercise
4851 Paramount Dr.
San Diego CA 92123
800-825-3636
www.ACEfitness.org

# Blood Health Questionnaire

Name: Date:

Please answer the following by checking **YES** or **NO**

| | **YES** | NO |
|---|---|---|
| Have you ever had a bleeding condition or a blood disease? | | |
| Do you have Sickle Cell Anemia, or any other blood conditions? | | |
| Have you ever had liver disease, viral hepatitis, or a positive test for hepatitis? | | |
| Have you ever had malaria? | | |
| Have you ever had, or come into contact with persons possessing a sexually-transmitted disease? | | |
| In the past 12 months have you had a tattoo applied, ear or skin piercing, accidental needlestick, or | | |
| come into contact with anyone else's blood? | | |
| Have you ever used needles to take drugs, steroids, or anything else not prescribed by yuour doctor? | | |
| In the past 12 months, have you had sexual intercourse with anyone who has ever used needles to | | |
| take drugs, steroids, or anything else not prescribed by their doctor? | | |
| Have you ever had a positive test for the HIV/AIDS virus? | | |
| In the past 12 months, have you had sexual intercourse with anyone who has HIV/AIDS or has had a positive test for the HIV/AIDS virus? | | |

*All subjects have the right to not complete the form if they chose, but they will be excluded for safety reasons.

*If a subject answers, YES but chooses not to disclose more information they will be excluded for safety reasons.

I have read, understood, and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name (Please print)-

Signature- Date-

# Caffeine Questionnaire

Please circle your response to each question.

1. Do you consume caffeine
    a. Yes
    b. No
2. In what form do you consume caffeine. Circle all that apply.
    a. Coffee
    b. Energy drink
    c. Soda
    d. Other: _____
3. How many days per week do you consume caffeine?
    a. Daily
    b. Most days (4-6 times per week)
    c. Occasionally (1-3 times per week)
    d. Rarely
4. What time(s) of day do you consume caffeine? Circle all that apply
    a. Morning
    b. Noon
    c. Afternoon
    d. Evening
5. How much caffeine do you have at a time?
    a. Small serving 8oz
    b. Medium serving 16oz
    c. Large serving 20+oz
6. Why do you consume caffeine?_____
    _____
    _____
    _____
    _____
7. How long have you been consuming caffeinated bevarages?
    a. <6 months
    b. 1-3 years
    c. 3+ years

**Key:**

Question 1: A=1, B=0

Question 2: Each one circled = 1

Question 3: A=2, B=2, C=1, D=0

Question 4: Each one circled = 1

Question 5: A=1, B=1, C=0

Question 7: A=1, B=1, C=0

| Question | Score |
|---|---|
| Question 1 | |
| Question 2 | |
| Question 3 | |
| Question 4 | |
| Question 5 | |
| Question 7 | |
| **Total:** | |

**Low: score of 0-3** – They are eligible to participate in this study with only 48 hours of abstaining from caffeine prior to the first exercise session.

**Moderate: score of 4-7** – If they are consuming caffeine daily, they must abstain from caffeine for two weeks prior to the first exercise session to be included in the study.

**High: score of 8-13** – This score indicates that they must abstain from caffeine for two weeks prior to the first exercise session to be included in the study.

# Consent Form

**The Effects of Acute Caffeine Supplementation on Repeated Sprint-Performance in College-aged Non-athletes: Differences in Gender**

**Why am I being asked to participate in this research?**

You are being invited to take part in a research study about the effects of caffeine supplementation on repeated-sprint performance. You are being invited to participate in this research study because you are a Northern Illinois University student that will give us a great insight as to how caffeine effects repeated-sprints. The primary purpose of this study is to investigate how caffeine affects performance in a repeated-sprint protocol in college-aged non-athletes. The secondary purpose is to highlight the gender-specific differences when supplementing caffeine to elicit an effect on repeated-sprint performance.

**Who is doing the study?**

The person in charge of this study is Michael Belbis, who is currently a graduate student in the Kinesiology and Physical Education department. Other graduate students from the Kinesiology and Physical Education department will be assisting with data collection and screening.

**What is the purpose of the study?**

By doing this study, we hope to learn if caffeine elicits an ergogenic benefit on repeated sprint performance in college-aged non-athletes, along with highlighting any gender-specific differences.

**Where is the study going to take place and how long will it last?**

The research procedures will be conducted at Anderson Hall on the campus of Northern Illinois University. You will need to physically come 3 times to Anderson hall. The first visit will take about 45 minutes to 1 hour, while the second and third visits will be about 1-2 hours. The total amount of time you will be asked to volunteer for this study is about 180-300 minutes over three days.

**What will I be asked to do?**

When you arrive, the first meeting will occur at the Exercise Physiology Lab in Anderson Hall. You will be required to sign this statement of informed consent, in addition, each you will complete a medical questionnaire known as the “Health History Questionnaire” to assess if you are cleared for vigorous physical activity. You will also complete a Blood Health Questionnaire for Finger Prick Blood Analysis along with a Caffeine Usage Questionnaire. You will also have some general health measures such as blood pressure and heart rate. If you display any medical problems or concerns, you will be unable to participate within the research study. If at any time

you uncomfortable about the screening questions you may opt to not complete the forms but this will lead to your exclusion from the study for safety precautions.

After completion of the consent, anthropometric data including height & weight will be collected, in addition to blood pressure utilizing a standard blood pressure cuff and sphygmomanometer. Upon completion of the anthropometric tests, you will schedule the two exercise sessions with the researcher. The two sessions will take place at least 3 days from the preliminary session. Furthermore, the two exercise sessions will be separated by 7 days. After scheduling the two exercise sessions, you will receive a list of caffeinated food and beverages to refrain from at least 48 hours or 2 weeks prior to the exercise session. Before you are dismissed, the researcher will put you through a "walk-through" session of the test, which will consist of 1 set of 6x30-meter sprints with 20 seconds of recovery in between. This familiarization trial will be done to help you gain an understanding on how to perform the exercise protocol.

You will be instructed to carry out their normal daily activities, but must refrain from organized physical activity (recreational fitness, strength & conditioning workout, etc.) at least 24 hours prior to the exercise sessions. Furthermore, if you considered a "heavy caffeine user", abstinence of caffeine for 2 weeks prior to the exercise session is required. Otherwise, at least 48 hours of caffeine abstinence is required for all participants. You will be allowed to consume a normal diet; however, you will be asked to refrain from usage of alcohol to prevent decline in performance during the exercise sessions during the second and third visits.

The second stage of the research will continue on the second and third meetings with the repeated-sprint training sessions. You will be asked to refrain from ingesting any food or beverages (except water) 1 hour prior to arriving for the exercise sessions. It is vital for you to ingest food and intake water throughout the day of the exercise session. You will be instructed to arrive on time to your scheduled session at the exercise lab in Anderson Hall to ingest either a caffeine or placebo capsule along with 200 mL of water. Blood pressure will be taken before ingestion of the supplement. After ingestion, you will either sit down for 45 minutes in Anderson Hall or attend your class in Anderson Hall. Your physical activity will be limited, along with your physical activity. You also may not ingest any food or beverages (other than water) during this wait period. After the wait period, you will report to Anderson 100 to start the repeated-sprint protocol, which will be conducted by the exercise physiology researchers. All measurements during the study will be recorded using standard data tables using paper and pencil materials. The testing will include a repeated-sprint protocol which will determine the effect of caffeine ingestion or a placebo on a repeated-sprint protocol, along with examining any differences in gender. Prior to the sprinting session, you will be taken through a brief light aerobic warm-up consisting of a light jog (50% Max Heart Rate) around the gymnasium for 5 minutes followed by 5 minutes of dynamic stretching exercises to increase blood flow to your muscles. The repeated-sprint protocol will consist of 3 sets of 6 x 30-meter sprints, which are standard protocols, not only used in various studies, but in athletic settings. Each set will consist

of performing 6 sprints of 30-meter sprints at your highest output/speed (90% of maximal heart rate). After each sprint, you will rest for 20 seconds before returning to the line for the next sprint. Each individual sprint will be timed using standard stopwatches, which will be added together to determine total sprint time. The sprint sets will be followed by a recovery period of 5 minutes.

During each rest period, you will be tested for blood lactate levels utilizing an approved method for finger prick blood lactate analysis using a Nova Biomedical Lactate Plus Lactate Meter. Finger prick blood analysis will be done in a safe area of the gymnasium room. Each blood sample and materials used to clean the subject's fingers will be disposed of using Bio-Safe containers.

After the finger prick blood analysis is complete, you will perform an active recovery protocol by walking at a low intensity pace of 50% maximum heart rate. Finger prick analysis will occur at rest before the start of the session, and at the beginning of each rest period for a total of 4 finger prick blood tests per participant. Along with measure blood lactate, the rating of perceived exertion using the Borg scale will be taken. You will be shown the BORG scale on a chart at the end of each sprint set. The last variable of measure will be heart rate using Polar Heart Rate monitors used in standard medical offices, hospitals, and research environments. The Polar heart rate monitor includes a chest strap sensory, and a watch receiver. The comfortable chest strap will be secured around the top of your torso underneath your clothing. The watch receiver will then be synced to the chest strap, reading the electrical impulses from your heart, and displaying your heart rate on the watch face. Heart rate will be recorded at rest at the beginning of the exercise session, and after the sprint set. After completion of the exercise session, you will participate in a cool-down session. This will consist of walking around the gym at a slow pace until your heart rate is under 50% of your maximum heart rate, along with static stretching of the lower body. After completion of the cool-down, you will be dismissed.

**Are there reasons why I could not qualify for this study?**

You may be excluded from this if you do not meet the inclusion criteria. The researchers will discern if you do not qualify. Participants will be excluded from participation if they do not meet the age requirements for the study and/or if they answer "Yes" to any of the questions in the HHQ Questionnaire and do not provide physical activity clearance from a doctor if contraindications are present. Some questions from the HHQ questionnaire and inclusion form include:

-Have you ever had a heart attack or stroke?

-Do you have a history of diabetes?

-Do you lose your balance because of dizziness or do you ever loss consciousness?

-Do you have cardiovascular disease or pulmonary disease?

-Is your doctor currently prescribing drugs for your blood pressure or heart condition?

-Could you be pregnant?

-Do you know of any other reason why you should not do physical activity?

The participants will also be screened using a Health/Blood Questionnaire for clearance for the finger prick blood analysis procedure. Participants will be immediately excluded if they answer "Yes" to any of the questions listed in the Health/Blood Questionnaire for Finger Prick Blood Analysis. The questions include:

-Have you ever had a bleeding condition or a blood disease?

-Do you have Sickle Cell Anemia, or any other blood conditions?

-Have you ever had liver disease, viral hepatitis, or a positive test for hepatitis?

-Have you ever had malaria?

-Have you ever had, or come into contact with persons possessing a sexually-transmitted disease?

-In the past 12 months have you had a tattoo applied, ear or skin piercing, accidental needlestick, or come into contact with anyone else's blood?

-Have you ever used needles to take drugs, steroids, or anything else not prescribed by your doctor?

-In the past 12 months, have you had sex with anyone who has ever used needles to take drugs, steroids, or anything else not prescribed by their doctor?

-Have you ever had a positive test for the HIV/AIDS virus?

-In the past 12 months, have you had sex with anyone who has HIV/AIDS or has had a positive test for the HIV/AIDS virus?

*If a participant answers "Yes" to any of these questions, the participant will be excluded from the study and it's testing procedures.

In addition, you will be excluded from this study if you are pregnant or have a good reason to believe you are pregnant. All other predetermined factors will be taken into account that may exclude you from this study.

**What are the possible risks and discomforts?**

The things you will be doing have no more risk of harm than you would experience in everyday life as an individual engaging in physical activity.

You must be aware that by participating in this study, you may sustain common musculoskeletal injuries that are associated with physical activity and interval training. Subjects may also experience delayed onset muscle soreness as a result of the training protocol, which is a normal and natural process of the human body as a result of physical activity. You may also develop a feeling of a light "burning" sensation in your legs during the testing due to an increased level of blood lactate in your muscles. This is normal and is usually dissipated within a few minutes. Typically, the side-effects of caffeine ingestion include insomnia, restlessness, stomach irritation, nausea, vomiting, increased heart rate and respiration, headaches, and anxiety. The caffeine dosage being given in this study are not be enough elicit these specific side-effects.

In addition, during the lactate testing protocol, risk of contact with blood from person to person will be minimized due to explicit procedures carried out by the investigator utilizing proper equipment such as gloves, alcohol wipes, and bio-hazard bins.

There are no other known potential risks associated with this study. You may, however, experience a previously unknown risk or side effect.

**Will I benefit from taking part in this study?**

Benefits from the study include knowledge of repeated-sprint training (high-intensity interval training), and caffeine supplementation. In addition, you will discover your physical capabilities through your performance in the interval training session and how caffeine affects it.

**Do I have to take part in this study?**

If you decide to take part in the study, it should be because you want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

**If I don't take part in this study, are there other choices?**

If you do not want to be in the study, there are no other choices except to not take part in the study.

**What will it cost me to participate?**

There are no costs associated with taking part in this study.

**Will I receive any payment or rewards for taking part in the study?**

You will not receive any payment or reward for taking part in this study.

**Who will see the information I give?**

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about this combined information. You will not be identified in these written materials. Only the testing facilitators will have access to your information, and all information will be coded with an ID number so your personal name will not be available.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from the information you give, and these two things will be stored in different places under lock and key.

**Can my taking part in the study end early?**

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to participate. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to end your participation in the study. They may do this if you are not able to follow the directions they give you or if they find that your being in the study is more risk than benefit to you.

**What happens if I get hurt or sick during the study?**

If you believe you are hurt or if you get sick because of something that is done during the study, you should call Michael Belbis at (708)-415-1371 immediately. It is important for you to understand that Northern Illinois University will not pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. That cost will be your responsibility. Also, Northern Illinois University will not pay for any wages you may lose if you are harmed by this study.

Usually, medical costs that result from research-related harm cannot be included as regular medical costs. You should ask your insurer if you have any questions about your insurer's willingness to pay under these circumstances.

**What if I have questions?**

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Michael Belbis at (708)-415-1371

**What else do I need to know?**

You will be told if any new information is learned which may affect your condition or influence your willingness to continue taking part in this study.

*I have thoroughly read this document, understand its contents, have been given an opportunity to have my questions answered, and agree to participate in this research project.*

_____ _____

Signature of person agreeing to take part in the study Date

_____

Printed name of person taking part in the study

_____

Name of person providing information to subject

# Inclusion Form

"The Effects of Acute Caffeine Supplementation on Repeated-Sprint Performance in College-aged Non-athletes: Differences in Gender"

**Screening Protocol:**

Date: _____ ID: _____

**Inclusion Criteria:**

Are you a healthy male or female between the ages of **18-30**? Yes No

Are you currently an NIU student? Yes No

**Exclusion Criteria:**

Are you currently an NIU college athlete? Yes No

Any past lower extremity muscle injuries that would affect results?* Yes No

Any past lower extremity skeletal injuries that would affect the results?* Yes No

Are you pregnant or could you be pregnant? Yes No

Are you currently taking any prescription medications?* Yes No

Any history of illness or disease that would affect study outcomes?* Yes No

Explain: * if answered YES, the decision to exclude will be made by the PI after a full disclosure by the subject.

_____ ____/____/_____

Name of person completing form Month Day Year

_____ Initials of person completing the screening

# APPENDIX C

# DATA SHEETS

**Caffeine supplementation study** **Visit 1** **2018**

Visit One

Name:_____ ID Number:_____

Date:_____ Time:_____

Age:_____ Gender: Male Female

Included or Excluded (Circle one)

If excluded, provide a reason?_____

_____

Checklist of forms: (Please circle)

Inclusion/exclusion form: Yes No Consent form: Yes No HHQ: Yes No

Blood Questionnaire: Yes No Caffeine Questionnaire: Yes No

---

Baseline Measurements:

Height:_____in.

Weight:_____lb. BMI:_____$kg/m^2$

Blood pressure (first attempt):_____mmHg

Blood pressure (second attempt):_____mmHg (if needed)

Issues:_____

_____

_____

Comments:_____

_____

_____

_____

**Caffeine supplementation study Visit 2 2018**

Visit Two

ID Number:_____ Date:_____ Age:_____

Gender: Male Female

---

**Supplement Ingestion**

Blood Pressure_____mmHg (measured before ingestion)

Supplement ingested: Caffeine Placebo Time ingested:_____ Initials of observer:_____

---

**Resting Measures** (taken 45 minutes after supplement ingestion)

Blood pressure:_____mmHg Resting HR:_____bpm RPE_____

Issues:_____

_____

_____

_____

---

**Warm up**

Age-predicted maximal heart-rate_____bpm

50% APMHR_____bpm

65% APMHR_____bpm

Light jog (3 minutes; max 65% APMHR) Yes No

Dynamic stretches (3 minutes) Yes No

**Training Session**

| **Pre-data** | **Blood Lactate** | **Heart Rate** | **RPE** |
|---|---|---|---|
| | | | |
| Notes: | | | |

| **Set 1**<br>**(20 seconds of active recovery in between sprint)** | **Sprint Number** | **Time** |
|---|---|---|
| | **1** | |
| | **2** | |
| | **3** | |
| | **4** | |
| | **5** | |
| | **6** | |
| | **Total Set Time:** | |

| **Set 1 Post-Measures** | **Blood Lactate** | **Heart Rate** | **RPE** |
|---|---|---|---|
| | | | |
| Notes: | | | |

| | | |
|---|---|---|
| **Set 2**<br>**(20 seconds of active recovery in between sprint)** | **Sprint Number** | **Time** |
| | **1** | |
| | **2** | |
| | **3** | |
| | **4** | |
| | **5** | |
| | **6** | |
| | **Total Set Time:** | |

| | | | |
|---|---|---|---|
| **Set 2 Post-Measures** | **Blood Lactate** | **Heart Rate** | **RPE** |
| | | | |

Notes:

| | | |
|---|---|---|
| **Set 3**<br>**(20 seconds of active recovery in between sprint)** | **Sprint Number** | **Time** |
| | **1** | |
| | **2** | |
| | **3** | |
| | **4** | |
| | **5** | |
| | **6** | |

| | Total Set Time: | |
|---|---|---|

| | Blood Lactate | Heart Rate | RPE |
|---|---|---|---|
| **Set 3 Post-Measures** | | | |
| Notes: | | | |

Post Notes/Issues:

## Caffeine supplementation study Visit 3 2018

Visit Three

ID Number:_____ Date:_____ Age:_____

Gender: Male Female

---

**Supplement Ingestion**

Blood Pressure_____mmHg (measured before ingestion)

Supplement ingested: Caffeine Placebo Time ingested:_____ Initials of observer:_____

---

**Resting Measures** (taken 45 minutes after supplement ingestion)

Blood pressure:_____mmHg Resting HR:_____bpm RPE_____

Issues:_____

_____

_____

_____

---

**Warm up**

Age-predicted maximal heart-rate_____bpm

50% APMHR_____bpm

65% APMHR_____bpm

Light jog (3 minutes; max 65% APMHR) Yes No

Dynamic stretches (3 minutes) Yes No

**Training Session**

| **Pre-data** | **Blood Lactate** | **Heart Rate** | **RPE** |
|---|---|---|---|
| | | | |
| Notes: | | | |

| **Set 1**<br>**(20 seconds of active recovery in between sprint)** | **Sprint Number** | **Time** |
|---|---|---|
| | **1** | |
| | **2** | |
| | **3** | |
| | **4** | |
| | **5** | |
| | **6** | |
| | **Total Set Time:** | |

| **Set 1 Post-Measures** | **Blood Lactate** | **Heart Rate** | **RPE** |
|---|---|---|---|
| | | | |
| Notes: | | | |

| |
|---|
| |

| | Sprint Number | Time |
|---|---|---|
| **Set 2**<br>**(20 seconds of active recovery in between sprint)** | **1** | |
| | **2** | |
| | **3** | |
| | **4** | |
| | **5** | |
| | **6** | |
| | **Total Set Time:** | |

| | Blood Lactate | Heart Rate | RPE |
|---|---|---|---|
| **Set 2 Post-Measures** | | | |
| Notes: | | | |

| | Sprint Number | Time |
|---|---|---|
| | **1** | |
| | **2** | |

| | | |
|---|---|---|
| **Set 3**<br>**(20 seconds of active recovery in between sprint)** | **3** | |
| | **4** | |
| | **5** | |
| | **6** | |
| | **Total Set Time:** | |

| | **Blood Lactate** | **Heart Rate** | **RPE** |
|---|---|---|---|
| **Set 3 Post-Measures** | | | |

Notes:

Post Notes/Issues:

# APPENDIX D

# FINGER PRICK PROCEDURE

**Finger Prick Procedure:**

1. Clean the area of the fingertip with an alcohol prep pad (1st – 3rd digit from the thumb).

2. This can be completed on the right or left appendage (on average 1-2 fingers will be pricked more than twice – 5 total).

3. Dry with gauze completely.

4. Prick the finger with a lancet (one time use, self-contained, deposal).

5. Wipe the first blood produced with a new dry gauze pad.

6. Squeeze the finger to produce a blood droplet and measure using the lactate plus.

7. Blood is collected on a test strip, which the device uses to measure blood lactate.

8. Place a dry gauze pad on the area and the finger prick will close in roughly about 1-2 minutes.

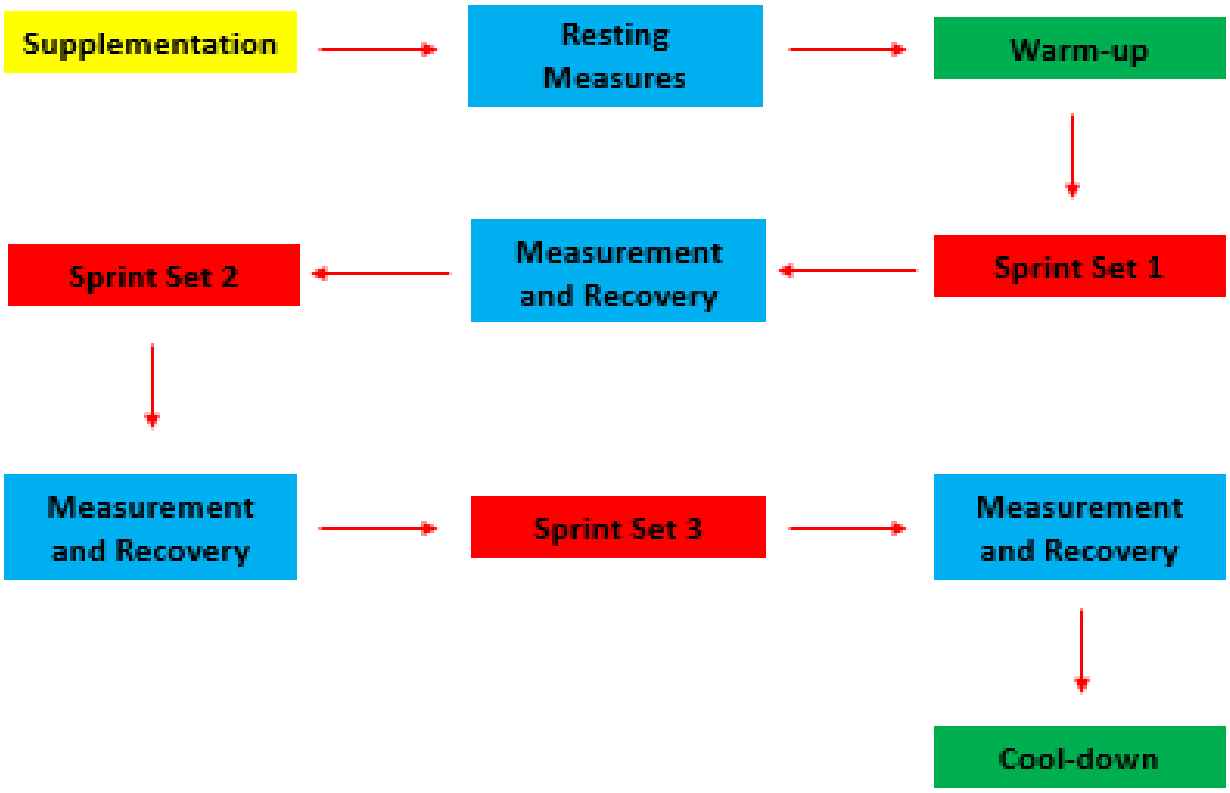
9. The lancet, gauze, and test strips that all had contact with blood are disposed of in a biomedical container.

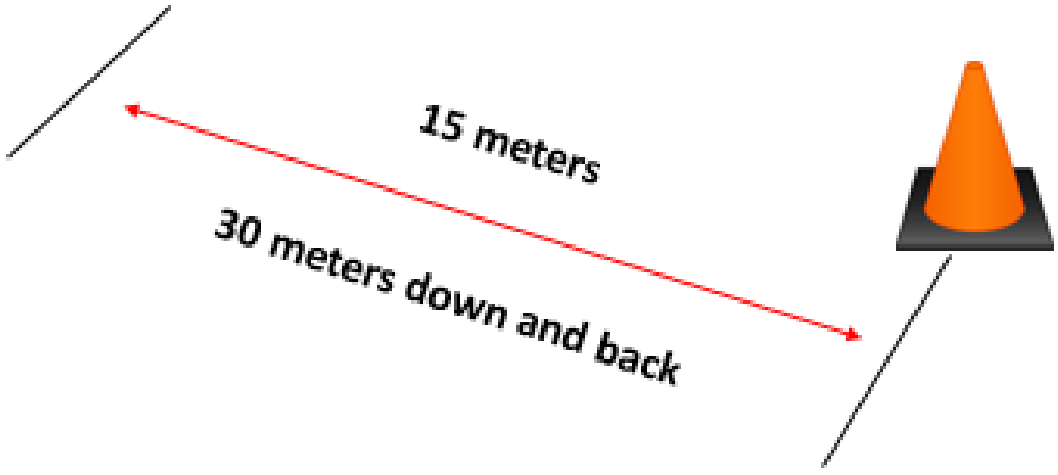
10. The dry clean gauze will be disposed of in a biohazard trash receptacle.

11. If a subject feels uncomfortable anytime during the test, we will discontinue this portion and they will be able to finish the other portions of testing.

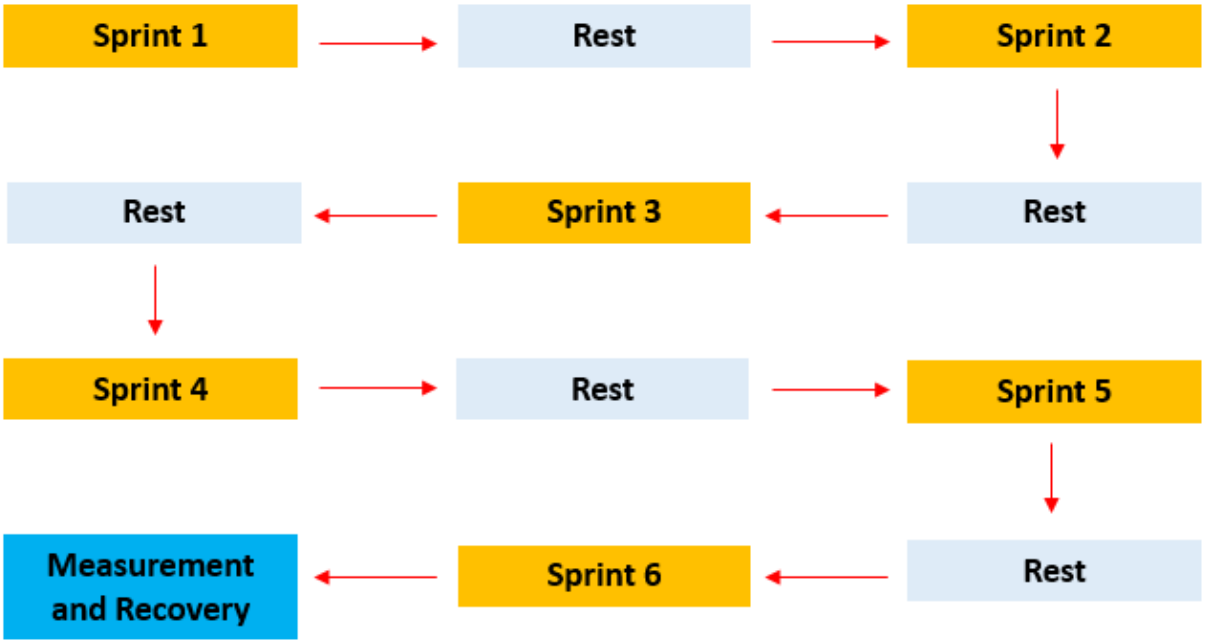
# APPENDIX E

# EXPERIMENTAL DESIGN LAYOUT




Six sprints = One sprint set


Sprint 1
Rest
Sprint 2
Rest
Sprint 3
Rest
Sprint 4
Rest
Sprint 5
Measurement and Recovery
Sprint 6
Rest