The Effects of Caffeine Supplementation in Division II Track Athletes During Multiple-Bout Mid-Distance Running Performance

By

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ABSTRACT

Caffeine supplementation has been shown to increase time to exhaustion in aerobic performance, but has not been examined in a field setting for multiple-bout mid-distance running performance. **Purpose:** The purpose of this study was to determine if caffeine supplementation had a positive effect on the overall performance in Division II male and female collegiate mid-distance athletes. Overall performance was ultimately determined by the participants' multiple-bout one-mile and 400-meter times on a 200-meter indoor track field setting. The secondary purpose of this study was to analyze heart rate and blood lactate levels during recovery after both bouts. **Methods:** Twelve Division II middle-distance track athletes (6 males/6 females) were assigned to a double-blind, equal randomization, crossover design study. Participants consumed 6 $mg \cdot kg^{-1}$ of NoDoz caffeine or placebo (sugar pill) one hour prior to a maximal effort one-mile bout followed by a structured recovery period; then they performed a maximal effort 400-meter bout. A total of two trials were performed, separated by one week. Each participant underwent each treatment. **Results:** Male participants' immediate post 400-meter HR placebo (PCB) vs. male immediate post 400-meter HR caffeine (CAF) was found to be significant ($p < .05$). For the females, statistical significance was found in the 5-minute pre-mile BL PCB vs. 5-minute pre-mile BL CAF ($p < .05$). There was no statistical significance for caffeine increasing overall running performance (time) in either the mile or 400-meter bouts for either genders. **Conclusions:** Though caffeine was not found to be statistically significant to benefit mile or 400-meter times, practically caffeine may be a viable method for improving performance based on observably faster mile and 400-meter times. However, more research is needed.

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CHAPTER 1: Introduction

Athletes are continuously on the lookout for ways of increasing their performance. Today in the twenty-first century the focus is on experimentation with dietary supplement consumption. Caffeine is the most widespread ingested drug in the world; approximately 87% of adults and children in the United States reported consistent usage of caffeine in their diet (Huntley & Juliano, 2012). Athletes use caffeine as an ergogenic aid for performance. Research by French, McNaughton, Davies, and Tristram (1991) supports that caffeine delays onset of muscle fatigue, increasing the body's ability to perform at a higher work rate. This results from the increase in free fatty acid (FFA) oxidization stimulated by intake of caffeine (French at al., 1991). The increase in FFA mobilization enables the body to reserve muscle glycogen stores until later in exercise, therefore increasing time to fatigue and blood lactate buildup (French et al., 1991).

Despite evidence showing an increase in work rate, there is major controversy whether caffeine is shown to provide significant aid to overall performance. The effects of caffeine on the physiological functions of heart rate (HR), blood lactate (BL), rate of perceived exertion (RPE), hydration and many other variables have been previously examined (Bridge & Jones, 2006; French et al., 1991; Glaister et al., 2008). According to Ramos et al. (2006) "lactate is the final product of the anaerobic glycolysis that occurs in hypoxic tissues, although well oxygenated tissues can, in certain conditions, produce lactate through aerobic glycolysis" (p. 44). Blood lactate is usually of interest during and post exercise because of the potential hindrance of muscular contraction affecting performance. As exercise time prolongs and intensity increases during exercise, a buildup of H^+ occurs which contributes to muscular fatigue (Baechle & Earle, 2008). Levels of post exercise

blood lactate production seems unclear according to research by Davis and Green (2009). Based on their research they suggest the blood lactate increase during and post-exercise may be from caffeine's stimulation of the central nervous system (CNS), which can dull pain perception (Davis & Green, 2009). The human mind can be a big limiting factor to overall performance. If caffeine can indirectly reduce pain perception of the brain, an athlete may be able to push their body further physiologically (eg. in this case, leading to increased lactate production). Participant's perception of effort was gathered in this study via Borg scale. According to Baechle and Earle (2008) the 15-point Borg scale from 6 (no exertion at all) to 20 (maximal exertion) is a good indicator of effort/intensity of an exercise bout.

Overall the data seems inconsistent; findings reveal minor increases in athletic performance (Hoffman et al., 2007) as well as no change in performance (Hunter, Collins, Lambert, and Noakes, 2002). Based on the inconsistent data, there is dispute whether caffeine ingestion leads to increased performance or not. These inconsistencies may be a result of various exercise types (eg. aerobic, intermittent, anaerobic), trained vs. untrained participants, and varying protocols used (dose of caffeine, timing of distribution, single vs. multiple bout exercise). As long as there is a possibility of even minor increases in performance, athletes will continue to consume caffeine as an ergogenic aid.

These inconsistent findings may also arise because researchers have not found the optimal testing protocol for determining a relationship between endurance athlete's performance and caffeine consumption. Differences between studies could be due to the amounts of caffeine given, time of distribution prior to test, habitual vs. non-habitual users, and the level of athlete (recreational vs. elite/experienced), to name a few variables. Research by French et al. (1991) showed that a large dose of caffeine (10 $mg \cdot kg^{-1}$)

immediately prior to exhaustive exercise results in increased performance due to subjects' increased ability to perform work. Surprisingly with the increased performance, they did not show any increase of heart rate in caffeine compared to placebo trials (French at al., 1991). Heat rate does not seem to be an indicator of increased performance when ingesting caffeine. Tarnopolsky, Atkinson, Macdougall, Sale, and Sutton (1989) and Birnbaum and Herbest (2004) also showed increase in performance to exhaustion from caffeine ingestion without significant change in their participant's heart rates. French et al. (1991) used a protocol of running until exhaustion in elite distance runners. The testing was performed in a controlled lab setting running at 75% VO_2max for 45 minutes then increasing by 2 mph until the subject stopped (French et al., 1991). Their study's classification of elite distance runners consisted of being an active runner and completing at least two marathons. There was no specification determining how fast they ran a marathon therefore leaving "elite" very unspecific (French et al., 1991). However, the participants had a VO_2max range of 57.9 ± 5.5 $ml \cdot kg^{-1}min^{-1}$. According to Ferguson (2014), a VO_2max between that range falls within the excellent to superior category. Therefore the participants of French et al. (1991) do have very good aerobic capacity for the exhaustive exercise protocol.

Ultimately testing of elite athletes would be ideal. Elite level athletes are keen to acute adaptations in performance and their bodies' buffering capabilities are superior to most recreational athletes (Burke, 2008). Not only would an elite athlete's H^+ buffering capabilities be beneficial to a study's reliability, but also their experience in a race setting giving 100% effort. Placing elite athletes in a field setting or race setting may result in a greater chance of 100% effort and psychologically push them to try and beat the other participants. Many studies use time to exhaustion protocol (fixed work rate) in a laboratory

setting which may not be ideal for measuring performance. The use of a field setting would be a better reflection of an athlete's performance since they are not fixed to a certain % of their VO_2max. Bridge and Jones (2006) and O'Rourke, O'Brien, Knez, and Paton (2008) both used field setting protocols which are more applicable to sport. On an outdoor track setting, Bridge and Jones (2006) found ingestion of 3 $mg \cdot kg^{-1}$ of caffeine one hour prior to testing resulted in a significant improvement in 8 km performance time compared to placebo. A similar study by O'Rourke et al. (2008) used a protocol distributing 5 $mg \cdot kg^{-1}$ of caffeine or placebo one hour prior to 5 km time-trial performance on an outdoor track. Each participant performed the 5 km time-trial twice, given caffeine for one trial and placebo for the other. Results indicated a significant benefit to performance with caffeine, 1.0 – 1.1% increase compared to placebo trials. With sport application, a 1% increase in performance for a 14:30 5 km race (level of male athletes in this study) could make the difference of running approximately 8.5 seconds faster; this could also be the difference of running 10.5 seconds faster in a 17:30 5 km race (level of female athletes in this study).

Within the research studies of Bridge and Jones (2006) and French et al. (1991) the subjects were non-habitual users and controlled to refrain from caffeinated items prior to testing. What if they were habitual caffeine users, would the results be affected? Findings from Tarnopolsky et al. (1989) state there is significant difference in physiological adaptation between habitual and non-habitual users; there is direct correlation with caffeine use and its effects on the body. A 4-day test and 15-hour test of abstinence was performed with habitual caffeine users. During the 4-day trial there was increase in FFA oxidization during exercise, but no appearance of a significant increase of FFA oxidization during the 15-hour abstinence. Refraining from use of caffeine prior to performance and

competition increases the likelihood to receive physiological benefits (eg. increased FFA levels, CNS stimulation, epinephrine levels etc.) (Tarnopolsky et al., 1989).

Experimentation with caffeine supplements and endurance performance has shown benefit (Bridge & Jones, 2006; French et al., 1991). Research specific to mid-distance running performance is not as thoroughly researched. There may be a difference in caffeine's benefits during a shorter maximal effort run (e. g. 800 – 3,000 meters) because of less reliance on the oxidative energy system compared to studies using time to exhaustion protocols. Additionally, there may be a difference in caffeine's effects during multiple mid-distance bouts let alone one bout itself. Since caffeine has been shown to increase post-exercise lactate levels compared to placebo, the proposed study may reveal the caffeinated trial's second bout (400 m) being affected by lactate accumulation. If lactate is not fully cleared in the caffeinated participants before they start the 400-meter trial, muscular contraction and performance could be negatively affected earlier in the 400-meter bout compared to placebo. However, performing more field setting protocols in the multiple-bout, mid-distance area may be necessary to determine caffeine's ergogenic performance effects.

Problem Statement

Is caffeine a beneficial stimulant that can be used for multiple bouts of mid-distance performance? Middle distance athletes in championship settings often compete in multiple max-effort track races separated by minimal rest. The lack of rest affects the second maximal bout. Is caffeine a viable method for improving performance in both bouts?

Purpose

The purpose of this study was to determine if caffeine supplementation had a positive effect on the overall performance in Division II male and female collegiate mid-distance athletes. Overall performance was ultimately determined by the participants' multiple-bout one-mile and 400-meter times on a 200-meter indoor track field setting. The secondary purpose of this study was to analyze heart rate and blood lactate levels during recovery after both bouts.

Hypotheses

Collegiate mid-distance athletes would see improvement in mile performance through the use of caffeine ingestion. However, caffeine ingestion would lead to higher levels of lactate production making the 400-meter bout slower compared to placebo. Furthermore, placebo trials would illustrate better lactate recovery compared to caffeinated trials. Heart rate levels would not reveal a significant difference when comparing the two treatments.

Delimitations

This study was delimited to the following:

1. Use of 12 collegiate mid-distance athletes from an NCAA Division II University, six males and six females.

2. The participants' mileage (62-110 miles/week) and intensity (70-85% of max heart rate) of training would not vary from their current personal schedule.

3. Testing took place in Adams State University's High Altitude Training Center (the Bubble) to control for climate conditions.

4. The study was performed at an altitude of 7,544 feet.

5. The distribution of 6 $mg \cdot kg^{-1}$ of caffeine was in anhydrous capsule form (moderate dosage).

6. A total of two separate testing sessions took place separated by one week of normal training regimen.

7. The repeated exercise bout protocol consisted of a one mile-run followed by a 400-meter run 30 minutes after.

Limitations

This study was limited to the following:

1. The athlete's fitness levels may vary depending on their current training schedule.

2. Complete accuracy of their responses/answers to the questionnaire.

3. Possibility of sickness or injury from one test period to another.

4. Complications of an athlete not showing up for one of the tests.

5. The athlete's amount of sleep and dietary intake days prior to the day of testing may affect performance. Sleep and dietary logs 24 hours prior to testing sessions were implemented for control.

6. A small sample size of Division II track athletes.

7. The effects of gender were not compared within this study because there are not enough males and females in each group to run a proper statistical analysis.

Assumptions

It was assumed that participants given caffeine would have better performance in the one mile and inferior performance in the 400 meters compared to the placebo treatment regardless of gender. With increased levels of blood lactate associated with caffeine use, it can plausibly be assumed their second bout of running would be harder to sustain. It was assumed that all participants would give maximal effort during both bouts. It was also assumed that participants would answer the questionnaire truthfully.

Definition of Terms

- Blood Lactate – Lactic acid releasing from muscles into the blood when oxygen uptake cannot meet the demands of muscular work.
- Caffeine – Stimulant used to potentially increase multiple bout mid-distance performance.
- Mid-distance (800-3,000m) athlete – Member of the Adams State University cross country/track and field team.
- Ergogenic aid – Any substance, equipment or modality used to increase performance, specifically caffeine.
- Exercise until exhaustion – Exercising for longer periods of time until the participant voluntarily decides they cannot maintain current activity.
- Free fatty acids (FFA's) – Fatty acids broken down from the triglycerides from adipose tissue which can be used as an energy source during aerobic exercise.

- Indoor 200 meter flat track – A track built indoors that is flat. Does not have any hydraulic or frame build bank corners for increasing race performance. Track surface made of polyurethane.

- Intermittent performance – Intervals/broken-up bouts of short exercise with periods of rest.

- Speed endurance – Running at full effort for distances ranging from 800 – 3,000 meters.

- Sympathetic Nervous System – Helps provide involuntary regulation of body functions; caffeine ingestion speeds up the SNS response (eg. heart rate, sweating).

CHAPTER 2: Review of Literature

Caffeine as an Ergogenic Aid

Aside from common recreational usage, caffeine is widely used as an ergogenic aid for athletics as well. According to Brown-Riggs (2013), "An ergogenic aid is any training or psychological technique, mechanical device, nutritional practice, or pharmacological agent that can improve exercise performance capacity or enhance physical strength" (p. 25). Stimulants used as ergogenic aids have dated back at least 40 years for improving performance. Keisler and Armsey (2006) support research suggesting that caffeine was being used in the 1970's to improve exercise performance. Caffeine use as an ergogenic aid became popular around this time.

How Caffeine affects the Body

Keisler and Armsey (2006) classify caffeine as a drug due to its lack of nutritional value; it is purely a stimulant. Caffeine is one of the most widely purchased commodities in the U.S. In terms of International commerce, caffeine is only second behind oil (Keisler & Armsey, 2006). Used as such a widespread stimulant throughout the world, it can be found in many forms. Some of the foods and beverages with the highest levels include coffee, tea, chocolate, cola, energy drinks, and even over the counter medications such as analgesics and diuretics contain caffeine (Woolf, Bidwell, & Carlson, 2008).

Within the athletic population, caffeine has been used in the forms of coffee, energy drinks, chewing gum, with the most prevalent being anhydrous caffeine, otherwise known as a caffeine capsule/tablet or powder. Woolf et al. (2008) suggest caffeine may reduce fatigue, improve concentration, and enhance mental alertness. Regardless of the form

taken, the body metabolizes caffeine in a similar manner (Woolf et al., 2008). Goldstein et al. (2010) describe caffeine's digestion process in the body and how caffeine stimulates the body physiologically. Absorption occurs through the gastrointestinal tract and is then circulated and absorbed by bodily tissues and metabolized through the liver. Caffeine is very soluble therefore allowing absorption through the blood-brain barrier and crossing the membranes of nerves and muscle cells. Goldstein et al. (2010) believe caffeine's main effect is more neurological than muscular, therefore relating to muscle contraction excitement and increased performance. Acheson et al. (2004) suggested that many of the effects caffeine has on the body are mediated via the sympathetic nervous system (SNS). During aerobic exercise the sympathetic nervous system involuntarily responds via neurotransmitters. This stimulates an increase in cardiac output and blood flow to skeletal muscle which occurs from increased noradrenaline (norepinephrine) spillover (Esler, 2011). The SNS and caffeine ingestion simultaneously work together in improving endurance performance. Therefore caffeine may not provide its muscular endurance benefits without the help of the SNS. According to Davis and Green (2009), the CNS is affected through mediation of the adenosine receptor antagonist. The adenosine compound consists of adenine and ribose which has been shown to contribute to vasodilation. Therefore caffeine stimulation of the CNS contributes to adenosine metabolism resulting in vasodilation and increased blood flow throughout the body (eg. skeletal muscle, smooth muscle, circulatory system, and brain) (Davis & Green, 2009).

Bruce et al. (2000) support CNS stimulation within their study which tested the enhancement of a 2000-meter rowing performance after ingestion of 6 and 9 $mg \cdot kg^{-1}$ of caffeine compared to placebo. They found improvement in rowing performance by 1.2% in

caffeinated trials compared to placebo, which may have resulted from caffeine's effect on the CNS and skeletal muscle (Bruce et al., 2000). Increased performance through CNS stimulation results from greater motor unit recruitment and alteration in neurotransmitter function (Bruce et al., 2000). Thus, the body's increased neurotransmitter precision and efficiency combined with more motor unit recruitment results in performance benefit. Sports requiring high motor skill recruitment will see benefit from caffeine ingestion (Bruce et al., 2000). According to Stuart, Hopkins, Cook, and Cairns (2005), high motor skill requirement tasks such as passing in rugby were increased. Their study resulted in 10% improvement in passing accuracy. During game pressure simulation, the rugby athletes had a 90% completion rate in caffeine trials as compared to 83% completion rate in the placebo trials. Caffeine's effect on cognitive and neuromuscular function was very prominent (Stuart et al., 2005). Often in pressured championship situations, an athlete must be responsive to the competition. A boost in cognitive function and reaction time with the use of caffeine may also contribute to increased mid-distance performance.

Research by McLellan, Kamimori, Voss, Tate and Smith (2007) demonstrated caffeine enhancing psychomotor vigilance along with increased physical performance measures in special force military units. The study was performed to determine the effects of caffeine on military training exercises while being in a state of sleep deprivation. Caffeine showed a positive effect on the soldier's alertness and diligent observations required during training (McLellan et al., 2007). Being more mentally alert during testing or competitions may correlate to increased athletic performance. During a race, especially a mid-distance race, being mentally alert is a crucial aspect of countering other competitors' moves (eg. sudden increase in pace). If caffeine is shown to increase mental alertness in

military performance, there is potential for those same benefits to be seen in sport specific application to racing.

Performance at Altitude

Regardless if you are at sea-level or at altitude, caffeine may provide similar physiological ergogenic benefits. However, use of caffeine at altitude may have slightly more of a performance benefit compared to at sea-level (Berglund & Hemmingsson, 1982). There is minimal research comparing caffeine supplementation at altitude vs. sea-level, therefore more research is needed in the area. However, Berglund and Hemmingsson (1982) did perform a study comparing the difference 6 $mg \cdot kg^{-1}$ caffeine has on cross country skiers at 984 ft. and 9514 ft. Their protocol was in the field (snow) racing 21km, and they time-trialed at both elevations with either caffeine or placebo. At 984 ft. results revealed a 1.7% (approximately 59 seconds) mean increase in caffeinated performances compared to placebo, whereas at 9514 ft. caffeinated participants had a mean increase in performance of 3.18% (approximately 152 seconds) compared to placebo (Berglund & Hemmingsson, 1982). As altitude increases, caffeine may produce more of a performance benefit to aerobic performance from caffeine-induced increases in stroke volume (Berglund & Hemmingsson, 1982). Caffeine ingestion simulates vasodilation of the blood vessels, allowing more blood into the heart, therefore more oxygenated blood being pumped out of the heart to working muscles (Berglund & Hemmingson, 1982). If there is more oxygenated blood being pumped from the heart with each beat, this may help reduce the effect of lower atmospheric partial pressure of oxygen (pO_2) at altitude.

Predominantly the largest effect altitude has on performance is seen in aerobic training, especially distance racing. The general population have acquired the misconception there is less oxygen (O_2) in the air making it harder to breathe. In reality, according to Powers and Howley (2012) there are identical amounts of O_2, CO_2, and N_2 in the air at sea-level and altitude. At altitude, pO_2 decreases which in turn makes O_2 extraction from the air into the lungs more difficult (Powers & Howley, 2012). Physiologically, the body must begin to compensate for decreased pO_2 once you reach elevations of ~3,900 ft. (Baechle & Earle, 2008). When the pO_2 is decreased, the body's ability to extract O_2 from the blood via capillaries [(a-v) O_2] for working muscles is decreased. As Newton's Law states, for every action there is an equal opposing reaction. In this instance of physiology, decreased (a-v) O_2 results in increased ventilation rate (VE) in order to meet the demands of muscular work. Altitude has such an effect on mid-distance and endurance performance that the National Collegiate Athletic Association (NCAA) conversion for racing a mile at altitude compared to sea-level is approximately 11 seconds (NCAA, 2014). Meaning that if an athlete races the mile at altitude, the pO_2 difference compared to sea level will slow their performance by approximately 11 seconds. Inversely to mid-distance and distance, there is a mid-point at which events approximately 400m and below must add on time due to the reduced air density. The NCAA (2014) requires .11 - .21 seconds added to your 400m time, meaning that racing a 400m at altitude is an advantage compared to at sea level. According to Powers and Howley (2012) anaerobic performance is increased at altitude because of the lower air density, which allows an athlete to sprint faster or jump higher since lower air density is associated with less friction/surface drag.

Anaerobic Performance

Minimal research is known about the effects caffeine has on anaerobic performance (eg. sprints & resistance training), especially short-term repeated bouts of maximal exercise (Glaister et al., 2008). Many research studies analyzing caffeine's effects on anaerobic bouts of exercise use the Wingate cycle test. Woolf et al. (2008) conducted a study involving 18 highly trained competitive male participants consuming 5 $mg \cdot kg^{-1}$ caffeine prior to a Wingate anaerobic power test. Their results indicated caffeine trials had higher peak power numbers compared to the placebo, and 78% of subjects had improved performance. Average power and minimum power were also greater in the caffeine trials, but there was no statistical significance compared to the placebo. Additionally, 50% of the participants had less of a power drop and a higher minimum power when taking caffeine than the placebo (Woolf et al., 2008).

According to Beck et al. (2006) ergogenic effects are controversial for resistance training exercises. Their research suggests a low dose of caffeine (2.1 - 3 $mg \cdot kg^{-1}$) consumption one hour prior to testing significantly increases upper body strength (1RM bench press), but did not affect lower body strength (1RM bilateral leg extension). Research conducted by Woolf et al. (2008) found total weight lifted with the chest press to be significantly greater in the 5 $mg \cdot kg^{-1}$ caffeine trial compared to the placebo, with 67% of participants showing a significant increase. The leg press on the other hand did not show a significant increase in performance during caffeine ingestion, yet 78% of the participants did show a slight increase during leg press.

Burke (2008) found similar results with 37 resistance trained males ingesting 6 $mg \cdot kg^{-1}$ of caffeine one hour prior to testing. Upper body strength (bench press) was increased by 2% compared to a placebo, while the lower body strength (leg press) resulted in no change. In research by Goldstein et al. (2010) findings revealed no significant increase in either bench press or leg press, given 6 $mg \cdot kg^{-1}$ of caffeine in 22 resistance trained males. Research is unclear and inconsistent when applied to caffeine ingestion prior to strength and power activities. The current research does not specify any reasoning as to why caffeine benefits upper body strength compared to lower body strength. Therefore, more research is needed to determine the effects caffeine has on strength and power performance (Goldstein et al., 2010).

Intermittent Performance

Intermittent team sports fall under activity lasting long periods of time combined with short bouts of high intensity (Goldstein et al., 2010). Glaister et al. (2008) conducted a study using 21 physically active males who ingested a caffeine capsule containing 5 $mg \cdot kg^{-1}$ or placebo one hour prior to testing. The participants performed a protocol of 12x30 meter sprints with a rest interval of 35 seconds. Results indicated all but one of the participants showed improvement in fastest sprint time. Counterproductive to increased initial speed, there was a 1.7% increase in fatigue over the period of all 12 sprints during caffeine trials. This suggests that caffeine will benefit one-time sprints, however using caffeine for multiple sprint bouts shows a negative effect.

Schneiker, Bishop, Dawson, and Hackett (2006) performed a study using amateur level team sport athletes, ingesting 6 $mg \cdot kg^{-1}$ of caffeine, and then following an intermittent

sport protocol on a cycle ergometer. The protocol was developed to simulate a team sport game as closely as possible. Participants performed 2x36 minute halves, where each half consisted of 18x4 second maximal exertion cycle bouts. Each sprint was separated with 100 seconds active recovery and 20 seconds passive recovery. In comparison to the placebo, caffeine increased performance in the first half (8.5%) and second half (7.6%) for total work. Correlating with total work, peak power was improved in the first half (7.0%) and second half (6.6%). There appears to be agreement between Glaister et al. (2008) and Schneiker et al. (2006) showing caffeine can increase initial intermittent performance, however may adversely lead to greater fatigue later in the competition/testing.

Stuart et al. (1998) performed a study on Australian rugby players performing circuits similar to game lengths. Their protocol consisted of seven circuits in each 2x40 minute halves, a 10 minute halftime period, 30 second intervals between circuits, and ingestion of 6 $mg \cdot kg^{-1}$ of caffeine. Two of the station activities were straight line 20-30 meter sprints. Results showed caffeine increased sprinting performance by 2.9% overall; broken down into halves, the first half increased sprint performance by 2.3% and the second half increased by 3.4% for caffeine compared to placebo. Research suggests caffeine ingestion in low-moderate doses may lead to increased repeated bout performance.

Aerobic Performance

Little research has been performed in the field setting for caffeine. Sport specific field studies or race protocols are more applicable to sport, regardless of intermittent or aerobic performance, however most studies are conducted in the laboratory. Irwin et al. (2011) suggests time-to-exhaustion protocols are less reliable compared to protocols using

a specific time to complete a set distance or amount of work because there is a large coefficient of variation (eg. psychological mindset pushing to exhaustion, onset of fatigue, using lab equipment, etc.). However, this does not infer caffeine will not benefit time to exhaustion protocols. According to Wu and Lin (2010) "caffeine intake enhances endurance and improves performance, particularly prolonged, intermittent, and exhaustive exercises." Yet protocols using specific distances, workloads, or time periods are more beneficial to examine caffeine's performance effects compared to time to exhaustion protocols. Thus why the proposed study used a specific race scenario in a field setting to imitate sport application.

According to Goldstein et al. (2010) "caffeine is an effective ergogenic aid for sustained maximal endurance activity, and has also been shown to be very effective for enhancing time trial performance." A research study conducted by Bridge and Jones (2006) used eight trained male participants; distribution of 3 $mg \cdot kg^{-1}$ caffeine capsule or a placebo was given prior to an 8km race in a field setting. Caffeine improved average times by 23.8 seconds or a 1.2% overall increase compared to placebo. Wiles, Bird, Hopkins, and Riley (1992) performed a study analyzing ten subjects with VO_{2max} values ranging from 63.9-88.1 $ml \cdot kg^{-1} \cdot min^{-1}$ and the effects of consuming 150-200 mg (~3-4 $mg \cdot kg^{-1}$) caffeine in coffee form prior to a 1500 meter treadmill time trial. Within the 1500 meter time trial, participants were able to push as hard as possible for the last 400 meters simulating a race kick. Findings resulted in an average of 4.2 second increase in overall performance for caffeinated coffee compared to de-caffeinated coffee. All ten subjects also showed an increase in speed during the final 400 meter kick period (.6 km/h) compared to the

placebo. A difference of .6 km/h would be the equivalent of approximately 10 meters (Wiles et al., 1992).

Doherty, Smith, Hughes, and Davison (2004) researched subjects cycling for two minutes at 100% maximal power output followed by a one-minute all-out sprint to see if 5 $mg \cdot kg^{-1}$ caffeine would have an ergogenic effect. The caffeine trial showed a significantly higher mean power output for the one-minute all-out sprint duration (794±164W) compared to the placebo (750±163W). Hoffman et al. (2007) performed cycle ergometer testing until exhaustion for ten physically active college-aged subjects (8 male, 2 women). The protocol consisted of ingesting 450mg of enriched caffeinated coffee (approximately 6 $mg \cdot kg^{-1}$) then cycling at 75% of VO_{2max} until exhaustion (unable to maintain work load). Caffeine trials resulted in significant improvement in endurance performance pedaling for a greater overall time period compared to placebo. Caffeinated trials had a range of 35.3 ± 15.2 minutes compared to placebo trials ranging from 27.3 ± 10.7 minutes (Hoffman et al., 2007).

Supplementation with caffeine appears to be beneficial for prolonged endurance activities (French et al., 1991; Goldstein et al., 2010; Hoffman et al., 2007). However, the shorter the distance (mid-distance) and higher intensity, the greater the chance of lactic acid production which may affect repeated bouts. Along with higher intensity running for shorter distances (speed endurance), caffeine may conflict with the body's ability to buffer lactate.

Lactate Production and Recovery

According to Bridge and Jones (2006), caffeine has an effect on physiological functions resulting in increased lactate production. Suggestions for increased lactate production include: an increase in FFA availability therefore decreasing lactate utilization in the muscles and increasing blood lactate amounts, also possible interference of pyruvate oxidization thus delaying lactate utilization. The longer or harder an exercise bout becomes there will eventually be a drop in blood pH, otherwise known as metabolic acidosis (Baechle & Earle, 2008). As long as exercise continues, this drop in pH will lead to fatigue. According to Baechle and Earle (2008) lactate may be correlated with fatigue, however it is not the cause of fatigue. At a pH of ~7, lactic acid cannot exist, but when there is an accumulation of H^+ through exercise, lactic acid begins to develop from reduction in blood pH (Baechle & Earle, 2008). This reduction in pH and increase in lactic acid through exercise leads to interference of muscular excitation-contraction and inhibition of calcium binding to troponin resulting in muscular fatigue. Also, when pyruvate oxidation is inhibited, acetyl-CoA is unable to be formed. When plenty of oxygen is present in the muscles pyruvate will be converted to energy, but if there is not enough oxygen present (anaerobic exercise) pyruvate will be converted to lactate. Thus lactate cannot be buffered by the muscles and turned back into an energy source (ATP) via krebs cycle. Lactic acid begins to accumulate in the muscles and blood (lactate), contributing to fatigue during exercise.

Bridge and Jones (2006) found in their study that three minutes post 8km performance, blood lactate levels were significantly higher in the caffeine trials compared to placebo distribution. The increased FFA levels and CNS stimulation from caffeine

ingestion may be the cause of elevated lactate levels compared to placebo trials. A combination of increased FFA levels prolonging time to fatigue and the CNS effect on pain perception could allow a longer sustained hard effort compared to placebo trials. Though pain perception may be reduced from caffeine, some studies reveal RPE levels remain similar between caffeinated and placebo trials (Bell et al., 2002; Bruce et al., 2000). Caffeine may not effect RPE at the end of a maximal aerobic effort because the feeling of giving 100% effort is similar no matter what treatment is given.

French et al. (1991) found that blood lactate levels during performance in elite runners were not any more elevated between caffeine and placebo participants. However, post exercise caffeine participants did show a noticeable increase in blood lactate levels. The lack of lactate fluctuation between caffeinated and placebo trials during performance may be from their level of physiological efficiency. Therefore their lactate thresholds and buffering capabilities are greater than the average athletes during exercise. For the difference in post exercise lactate results, this may also be a result of CNS stimulation and increased FFA levels as stated previously. The proposed study may reveal these elevated post-exercise lactate levels which in turn may negatively affect their second running bout.

Free Fatty Acid Concentrations

Along with caffeine's prominent effects on the neuromuscular and cognitive functions, caffeine also has shown high stimulation of FFA's. French et al. (1991), Goldstein et al. (2010), and Hoffman et al. (2007) agree that caffeine ingestion results in increased fat oxidization through mobilization of FFA's from adipose tissue or intramuscular fat stores. Wu and Lin (2010) performed a resistance training study observing how the body's

hormones and substrates vary during post resistance exercise. They used a protocol of performing eight exercises, three sets of ten repetitions at 75% 1 rep max either on 6 $mg \cdot kg^{-1}$ caffeine or placebo. After taking blood samples 0, 15, and 30 min post exercise their results indicated significant increases in FFA levels and decreased growth hormone levels for caffeinated trials. The increased mobilization of FFA's allows fat to be utilized as a primary source of energy slowing glycogen depletion. Sparing glycogen stores will delay onset of muscle fatigue and increase work performance (French et al., 1991). French et al. (1991) furthermore state increases in FFA levels impede phosphofructokinase resulting in sparing of glycogen stores, otherwise known as carbohydrate sparing. An increase in FFA stimulation will most commonly affect endurance performance due to the delay in glycogen store depletion.

Jackman, Wendling, Friars, and Graham (1996) suggest caffeine supplementation should not have significant influence on anaerobic performance. During anaerobic exercise the predominant energy sources are ATP stores, muscle glycogen and blood glucose (Baechle & Earle, 2008). Thus caffeine's sparing of muscle glycogen through the use of FFA's is not relevant in short-term exercise since fat metabolism is not important (Jackman et al., 1996). However, with a multiple bout of exercise, the first being aerobic and the second being anaerobic, caffeine may be beneficial. If caffeinated trials spare more muscle glycogen than the placebo trials for the first bout of exercise, the caffeinated trials should in turn have more anaerobic energy fuel (glycogen/glucose) for the second bout. This should lead to increased performance and higher lactate levels.

Trained vs. Untrained Participants

Athletic populations are known to have fine-tuned physiological systems and buffering capabilities. According to French et al. (1991), athletes that are well trained have better capacity to utilize caffeine for an ergogenic effect compared to an average individual. These authors assume that only highly trained individuals are capable of physiological adaptations such as enhanced regulation of acid-base levels. However, caffeine may benefit the populations both highly trained and untrained. The extent to which performance is increased will be in relation to an individual's fitness level. Regulation of H^+ is essential for caffeine to show ergogenic benefits (Goldstein et al., 2010). When an individual is unable to buffer H^+ in the body there is a buildup of lactic acid in the muscles inhibiting muscular contraction leading to fatigue.

Lorino, Lloyd, Crixell, and Walker (2006) performed a study analyzing the effects of caffeine (6 $mg \cdot kg^{-1}$) on athletic agility and Wingate anaerobic power testing. Results indicated non-trained individuals given caffeine did not perform significantly better in either the pro-agility run or 30 second Wingate test. In a study by Collomp, Caillaud, Audran, Chanal, and Prefaut (1990) a dose of 4.3 $mg \cdot kg^{-1}$ was given to both trained and untrained participants prior to two maximal 100-meter freestyle swims. Of the caffeinated trials, results indicated a larger increase in swim velocities for the trained group of swimmers (1.5-1.6 $m \cdot s^{-1}$) compared to the untrained swimmers (1.1-1.2 $m \cdot s^{-1}$). Thus, untrained individuals may experience minor increases in performance through use of caffeine, however not as significant as trained individuals.

Bruce et al. (2000) suggest that another advantage highly trained athletes have is familiarity to testing environments. The majority of athletes undergo various tests throughout their athletic career which need to be taken into consideration as an advantage over non-trained individuals (Bruce et al., 2000). Highly trained athletes have the familiarity of giving 100% effort in race scenarios making them more reliable for test re-test protocols. A recreational athlete may have a misconception of a true 100% effort leading to inconsistent data. Trained individuals are well disciplined with mental and physical preparation which may contribute to better and consistent performances in testing scenarios. Where most testing is conducted in a laboratory setting, experienced athletes are going to feel more comfortable and confident performing a study that is in their field (eg. indoor track).

Dosage

Caffeine ingestion has been experimented with in various amounts with the aim to increase performance. The optimal dose of caffeine for performance benefits tends to vary dependent on exercise type. Pasman, Van Baak, Jeukendrup, and De Haan (1995) examined the effects of different doses of caffeine in nine well-trained cyclists. The participants performed six rides to exhaustion at 80% of maximal power output using an electromagnetically braked cycle ergometer. The participants were given a placebo, and a range of caffeine from 5, 9 and 13 $mg \cdot kg^{-1}$. Results indicated there was significant increased endurance performance for all caffeine trials compared to the placebo. Endurance performance compared to placebo increased by 47 ± 13, 58 ± 11, 59 ± 12 and 58 ± 12 min for 0, 5, 9 and 13 $mg \cdot kg^{-1}$ body weight of caffeine, respectively (Pasman et al., 1995). The caffeine ingestion resulted in comparable results between the different doses.

The cyclists performed at an average of 27% more efficiently with caffeine combined compared to the placebo.

Graham and Spriet (1995) also performed a study of similar protocol distributing three separate doses during endurance activity. Distribution of caffeine ranged from 3, 6, and 9 $mg \cdot kg^{-1}$. A significant performance increase was found within the 3 and 6 $mg \cdot kg^{-1}$ but not for a dose 9 $mg \cdot kg^{-1}$. A hypothesis to try to explain their findings was "On the basis of subjective reports of some subjects it would appear that at that high dose the caffeine may have stimulated the CNS to the point at which the usually positive ergogenic responses were overridden" (Graham & Spriet, 1995). Therefore caffeine may stimulate the CNS and SNS to an optimal level where performance benefits are shown. If the brain is over-stimulated from caffeine, there may be an inverse physiological response inhibiting its performance benefit. A systematic review by Ganio, Klau, Casa, Armstrong, and Maresh (2009) stated "performance improvements with caffeine ingestion are maximized with amounts up to 6 $mg \cdot kg^{-1}$". Caffeine is found to enhance performance of various types of exercise when ingested in low-to-moderate doses (~3-6 $mg \cdot kg^{-1}$); there is not any more of a benefit consuming larger doses (≥ 9 $mg \cdot kg^{-1}$) (Graham & Spriet, 1995).

Bruce et al. (2000) conducted research on competitive rowers with results supporting Graham and Spriet's (1995) findings about higher doses of caffeine not having as significant of an increase on performance. Eight competitive oarsmen completed three trials of a 2000-meter rowing test on an air-braked ergometer. Distribution of a placebo, moderate amount of caffeine (6 $mg \cdot kg^{-1}$) and a larger amount (9 $mg \cdot kg^{-1}$) were given to the oarsmen. Findings resulted in the smaller amount of caffeine improving overall time by

1.3% and the higher dose improving by 1.0% compared to the placebo for a 2000-meter row (Bruce et al., 2000). Though their findings resulted in statistical insignificance between the two caffeine doses, with relation to sport specific application there is a significance. A difference of .3% in a 2000-meter row can be the difference in winning or losing by seconds.

According to Desbrow et al. (2012), larger doses of caffeine circulating in the body do not result in increased performance. They conducted a study on cyclists performing three 60-minute time trials while given either 3 $mg \cdot kg^{-1}$ or 6 $mg \cdot kg^{-1}$ of caffeine. The results indicated a larger ergogenic effect from a smaller dose of caffeine. Time trial performance was increased by 4.2% for the smaller dose and a respectively smaller increase of only 2.9% for a larger dose when compared to the placebo (Desbrow et al., 2012). A suggestion can be made that a small to moderate dose of caffeine (~3 - 6 $mg \cdot kg^{-1}$) is optimal ingestion for participants to increase performance in endurance activities (Goldstein et al., 2010).

Possible Adverse Effects

Caffeine ingestion has potential to cause adverse effects; the effects are dependent on the dose of caffeine taken. Brown-Riggs (2013) include possible adverse effects such as rapid heart rate, increased blood pressure, dizziness, locomotor agitation, insomnia, irritability, increased anxiety, feelings of hypoglycemia and even bowel disruption during caffeine use. Large amounts of caffeine over 900mg (12.5 $mg \cdot kg^{-1}$ for a 70 kg person) may result in seizures and arrhythmias (Keisler & Armsey, 2006).

There are also possible side effects following a withdrawal period from caffeine. These symptoms include headache, irritability, increased fatigue, drowsiness, decreased alertness, difficulty concentrating, and decreased energy levels (Irwin et al., 2011). Symptoms may occur when cutting caffeine for short periods of time, as quickly as three days in non-habitual users and as early as 12 hours in habitual users; however the symptoms have a short lived effects (Keisler & Armsey, 2006). In the proposed study, participants experienced some minor symptoms from the sudden ingestion of 6 $mg \cdot kg^{-1}$ caffeine, such as jitteriness and increased alertness. Regardless if the participants are habitual users or caffeine naïve, a 48 hour abstinence period will help cleanse their body of any caffeine. Therefore, the dose of caffeine distributed in the proposed study resulted in side effects lasting for only a few hours.

Habitual vs. Non-Habitual Users

A larger factor influencing caffeine's effect on performance is the abstinence period from caffeine before testing. Tarnopolsky et al. (1989) found habitual caffeine users undergoing a four-day abstinence period prior to testing showed an increase in FFA levels. A shorter abstinence period of fifteen hours prior to testing did not result in increased FFA levels for habitual caffeine users. For caffeine to have maximal effects on performance, it would be beneficial to abstain from any caffeine ingestion for 48 hours or more for habitual users. Habitual users need an abstinence period to cleanse their body of any ergogenic effects caffeine has on the body. A cleanse period will reset the body, allowing caffeine's influence on the body physiologically to have full effect.

Research suggests caffeine's effects will be different between habitual and non-habitual users. Gwacham and Wagner (2012) found caffeine naïve participants had more of an ergogenic effect than those who frequently consumed coffee in the month prior to the testing (habitual users). They also showed caffeine ingestion increased cycling time to exhaustion for nonusers compared to regular caffeine users. The magnitude of increased performance from caffeine intake directly corresponds to how accustomed an individual is to caffeine (Gwacham & Wagner, 2012). Habitual caffeine consumers did not show signs of increased muscle contraction force at low speed contraction or high stimulation frequencies, therefore no benefit (Tarnopolsky et al., 1989). This study suggests lack of muscular stimulation in habitual users may indicate tolerance to neuromuscular effects of caffeine. However, Goldstein et al. (2010) suggested otherwise for caffeine habituation. A moderate dose of caffeine given to both users and nonusers resulted in enhancement of performance for both groups; however, there was a difference for lasting effects of the caffeine. The nonusers resulted in treatment effects lasting approximately three hours longer than habitual users. Further research seems to be needed to more clearly define caffeine's effects on habitual vs. non-habitual users.

Diuretic Effect

Caffeine has long been perceived as a significant form of diuretic. More recent research states otherwise. According to Majumdar and Kravitz (2008), consumption of caffeine beverages during exercise will hydrate nearly identical to non-caffeinated beverages. A study from Armstrong (2002) stated that urine loss was similar between caffeinated beverages and water; after fluid consumption, caffeine trials (100-680 mg) showed fluid retention up to 84% and water up to 81%. Tolerance to caffeine may reduce

the risk of fluid/electrolyte loss. Burke (2008) argues that caffeine beverages consumed within the ergogenic range do not alter urine losses or sweat rates during exercise. Large daily intakes of caffeine or abrupt increases in consumption have also been shown not to influence body fluid balance any more than consumption of water. As a person increases their consumption of fluid significantly, there will be direct correlation to urine loss no matter the fluid ingested. Burke (2008) suggests athletes consuming any form of caffeine (up to 13 $mg \cdot kg^{-1}$) do not need to alter/increase their fluid intake to accommodate for caffeine.

Roti et al. (2006) performed a study examining the possible effects caffeine has on sweat rates during submaximal exercise. A group of 59 active males consumed 3 $mg \cdot kg^{-1}$ caffeine for six days, and then on days 7-12 the participants split into three groups consuming 0, 3, or 6 $mg \cdot kg^{-1}$ caffeine. The submaximal exercise protocol used was walking at 1.56 m/s at 5% grade. Findings through urinary and blood samples concluded sweat rates did not vary statistically between groups nor negatively affect fluid-electrolyte balance (Roti et al., 2006). Urinary samples were examined by osmolality, urine specific gravity, and color; where blood plasma was examined by osmolality, and total plasma proteins (Roti et al., 2006). Roti et al. (2006) did suggest that caffeine ingestion, at rest, has the effect of blocking of sodium reabsorption in the kidney which leads to increased sodium and water excretion and less potassium excretion; however this response has not been observed during exercise. Therefore the participants in the proposed study did not need to alter from their normal fluid intakes since caffeine was being observed during performance.

Armstrong (2002) suggests caffeine intake less than 300mg (approximately 4 $mg \cdot kg^{-1}$ for a 70kg person) will induce a small diuretic effect but none greater than water. His research does not support caffeine affecting fluid-electrolyte balance to the point of performance disruption.

> Armstrong (2002) concluded the following:
>
> Direct laboratory comparisons of caffeine (361-567mg) verses placebo trials, conducted in 25-29°C ambient conditions, revealed no differences in core body temperature, sweat rate, plasma volume shifts, or performance times for 21-km competitive foot races. Thus, no research evidence indicates that caffeine consumption is detrimental during exercise in hot environments, when fluid losses are likely to be maximal. (p. 201)

Research also supports a benefit to caffeine ingestion during recovery. Armstrong's (2002) findings suggest during 2-6 hours of rehydration, using 250-379 mg caffeine (approximately 3.5 – 5.5 $mg \cdot kg^{-1}$ for a 70kg person), can result in increased Na^+ and decreased K^+ loss compared to water consumption. According to Roti et al. (2006) "part of the diuretic action of caffeine at rest includes blocking of Na^+ reabsorption in the kidney, which results in increased Na^+ and water excretion and decreased K^+ excretion." Research by Burke (2008) presented improved muscle glycogen re-synthesis after intake of 8 $mg \cdot kg^{-1}$ caffeine during four hours recovery. When caffeine was co-ingested with carbohydrate, there was a 66% increase in glycogen re-synthesis (Burke, 2008). With a large increase of glycogen re-synthesis through caffeine and carbohydrates ingestion, this method of recovery may be beneficial to athletes who participate in multiple bout sports.

Caffeine Legality

In 1999, the World Anti-Doping Agency (WADA) was created as an independent international organization regulating, promoting and fighting against use of sport doping in all forms (Burke, 2008). The organization took over that specific role from the International Olympic Committee (IOC) and established their first international regulations on January 1, 2004. According to Goldstein et al. (2010) caffeine is not a banned substance by the WADA, however, is on the monitoring program which regulates amounts too high during competition. The IOC mandates an allowable limit of 12 μg/ml of urine while the National Collegiate Athletic Association (NCAA) mandates an allowable limit up to 15 μg/ml of urine (Goldstein et al., 2010). Woolf et al. (2008) puts dosage into perspective; it takes approximately 13 $mg \cdot kg^{-1}$ body weight to reach maximum allowable limits of caffeine. This is the equivalent of 700 mg of caffeine or approximately seven cups of coffee at one time. Goldstein et al. (2010) suggests there are variations with these doses dependent on factors of gender and body weight. Keisler and Armsey (2006) speculate that women may have varying responses to caffeine compared to men because of estrogen levels, though not proven. However some elite female distance athletes have low body composition, therefore low estrogen levels. This may in turn cause caffeine's ergogenic benefits to respond similar for men and women. Regardless, the hemodynamic effects are comparable between both genders. Training status, habituation, and different coffee blends may also vary the amount of caffeine needed to reach allowable limits.

Timing of Caffeine Distribution

Pre-test distribution of caffeine is a grey area of research since it isn't the main factor affecting performance. Research by Goldstein et al. (2010) supports that the

majority of research protocols use a distribution of caffeine 60 minutes prior to testing for optimal absorption. According to Keisler and Armsey (2006), 90% of caffeine is cleared from the stomach in the first 20 min of ingestion, indicating that caffeine is rapidly absorbed through the gastrointestinal tract. The absorption process happening so quickly leads to peak blood plasma concentrations of caffeine in 40-60 minutes. This may be why there are fewer research protocols following a shorter time of distribution. Keisler and Armsey (2006) state that the timing of caffeine intake does not alter the ergogenic effects caffeine has on performance. Though the ergogenic effects will remain similar dependent of the timing of ingestion, the distribution of caffeine 60 minutes prior to activity is shown to reveal peak levels in the blood stream (Goldstein et al., 2010; Keisler & Armsey, 2006). Therefore if an individual is using caffeine to supplement their performance, it would be most beneficial to ingest caffeine a full hour prior to activity to ensure complete absorption.

Caffeine Form

Distribution of caffeine in research studies mostly consists of the anhydrous form, although some of the studies used coffee and energy drinks. Aside from the research of caffeine distribution forms, there are many other substances containing caffeine used during everyday sport activities. According to Ganio et al. (2009), a survey of the 2005 Ironman Triathlon World Championship athletes revealed 78% of respondents intended to use caffeine cola drinks and 42% intended to use caffeine gels. Graham, Hibbert, and Sathasivam (1998) performed a study using conditioned runners who performed five runs to exhaustion on a treadmill at 85% VO2max. The study compared ingestion of 4.45 $mg \cdot kg^{-1}$ caffeine as capsules, regular coffee, decaffeinated coffee, decaffeinated coffee plus capsule form of caffeine, and a placebo. Results indicated that the caffeine capsule alone provides

the largest ergogenic aid; performance was increased significantly allowing the participant to travel an additional 2-3 km (7.5 – 10 minutes) further than the four other conditions (Graham et al., 1998). The three other caffeine treatments did not show a significant difference in performance compared to the placebo.

The ingestion of anhydrous caffeine as compared to a cup of coffee has been shown to be more beneficial for improving performance (Goldstein et al., 2010). Goldstein et al. (2010) suggest derivatives of chlorogenic acids are produced while roasting coffee. These derivatives from roasting coffee may inhibit the effects caffeine has as an adenosine antagonist; therefore diminishing the action of vasodilation from adenosine. Birnbaum and Herbst (2004), and Graham, Hibbert, and Sathasivam (1998) support in their research that performance will be influenced the greatest during ingestion of caffeine in capsule form rather than coffee. Graham et al. (1998) suggest that coffee consists of substances which antagonize the possible ergogenic of caffeine. As a biological substance, coffee is made through roasting the beans, grinding, and then extracting in hot water. Throughout this process there are many compounds which are dissolved into the grounds. For example, lipids, carbohydrates, and proteins make up >60% of compounds where caffeine is only ~2% (Graham et al., 1998). Therefore the purity of an anhydrous caffeine capsule is more readily absorbed as an ergogenic aid where the compounds within coffee may be antagonistic to performance benefits.

Conclusion

A majority of the research on caffeine supplementation is in a laboratory setting (Bell et al., 2002; Burke, 2008; Wiles et al., 1992). Laboratory settings may not always be

the most beneficial for maximal effort testing due to the fixed work rates of a treadmill. However, some of the research had participants perform in a time-trial or field setting which may be a better application to measuring increases in performance (Bridge & Jones, 2006; O'Rourke et al., 2008). The freedom of the field setting on a track allows for the participant to maneuver and "race" to their tactical advantage in pursuit of 100% effort. According to Goldstein et al. (2010) "Caffeine is an effective ergogenic aid for sustained maximal endurance activity, and has also been shown to be very effective for enhancing time trial performance". Therefore more examination of multiple-bout, mid-distance performance (eg. 800 – 3,000m) is needed to determine if caffeine results in performance increases similar to longer endurance activities. Conducting studies involving trained athletes performing multiple-bout performances in the field setting may contribute to the understudied area of mid-distance caffeine supplementation.

CHAPTER 3: Procedures

The purpose of this study was to determine if caffeine supplementation had a positive effect on the overall performance in Division II male and female collegiate mid-distance athletes. Overall performance was ultimately determined by the participants' multiple-bout one-mile and 400-meter times on a 200-meter indoor track field setting. The secondary purpose of this study was to analyze heart rate and blood lactate levels during recovery after both bouts.

Field Setting

Testing took place on the indoor track in the high altitude training center (HATC), also known as the Bubble, at Adams State University in Alamosa, Colorado, at an elevation of 7,544 feet. The Adams State indoor facility controlled for any possible environmental factors.

Participants

Six male and six female collegiate mid-distance track athletes from an elite NCAA Division II University (Adams State University) were asked to volunteer for testing. They had a background of 7.5 ± 2.5 years racing mid-distance (eg. 800m – 3,000m). Men's training volume averaged 90 ± 20 miles/week and women's training volume averaged 62.5 ± 12.5 miles/week. Participants were selected based on ability to perform a one-mile run test and individual health. Men's mile times at sea-level averaged 4:23 ± 13 seconds and women's mile times at sea-level averaged 5:13.5 ± 1.5 seconds; however their altitude converted mile times would be approximately 11 seconds slower for the males and approximately 13 seconds for the females. Preferably, participants were similar in mile

time performance to better control the results of the study and provide an atmosphere similar to an actual race. Women and men were tested separately by gender to simulate a competition setting. Selection of participants with similar endurance capacities helped control psychological race aspects, such as intimidation and lack of confidence to win. An equal race setting contributed to increased validity of race results.

Instrumentation

Athletes were tested on a 200-meter indoor NCAA certified polyurethane rubber track surface. The track had metal rails on the inside of lane one to prevent athletes from cutting the curves. A standard Borg rating of perceived exertion scale (6-20) was used to measure RPE to determine participant's perception of effort immediately post one-mile and 400-meter bouts. Each participant wore the T31 Polar transmitter chest strap and watch to gather pre- and post-testing HR. In order to gather pre- and post-trial blood lactate levels, the Lactate Plus analyzer, Nova Biomedical lactate test strips and lancets was used. Trials were timed using the ChronoTap – Stopwatch application created by Kodeman Industries.

Research Design

Each participant who volunteered was required to complete a questionnaire before they were selected for the study (see appendix A). Participants were asked about the frequency of caffeine ingestion, personal best one mile time (sea-level), health restrictions, demographics, mileage per week, and willingness to participate. Based on their responses, six participants of each gender were asked to participate in the study. Health and safety (eg. heart conditions, allergies to caffeine, etc.) was the number one priority for being selected

to participate. Along with health and safety, the participants' mile times (sea-level), weekly mileage, and frequency of caffeine consumption (preferably non-habitual) were the deciding factors for study admission. The participants that grouped closest in these categories, especially mile times, were chosen to participate in the study. After showing interest and being selected as suitable to participate in the study, participants were required to sign an informed consent form approved by the IRB committee at Adams State University (see appendix B).

A randomized double-blind crossover design was used during this experimental study. A dose of 6 $mg \cdot kg^{-1}$ of caffeine in anhydrous capsule (NoDoz) form or placebo (sugar pill that looks and tastes similar) was distributed to participants 60 minutes prior to testing. The distribution of caffeine or placebo was overseen by the double-blind personnel to ensure proper ingestion. All men together, and women together (separate trials), performed under both conditions. During each trial there was equal randomization between the participants (3 caffeinated women/3 placebo women and 3 caffeinated men/3 placebo men). Participants knew they would eventually get caffeine during one of the trials, they just didn't know which trial. Participants ran a maximal effort one-mile run, were given 30 minutes active recovery, and then ran a maximal 400-meter run. The study consisted of a total of two experimental trials, with each trial separated by one week of recovery allowing adequate recovery. Participants performed the same structured warm-up (see appendix C) and structured recovery period between the mile and 400-meter bout (see appendix D). Prior to each trial, participants were asked to refrain from ingesting any caffeine for a full 48 hours. They were required to keep a 24-hour food log prior to each

trial to replicate similar diets for each trial. Also, participants refrained from any food consumption 1-hour prior to caffeine or placebo ingestion.

If there were any incidences of a participant becoming too sick or injured prior to the first trial session, a different individual who filled out the questionnaire would have been asked to volunteer in their place. However, if there was an incidence where a participant became too sick or injured between trials one and two, their data would have been separated from other participants. This process also applied to the chance of a participant not showing up to one of the trials. No participants dropped from this study, however there were a couple of complications that occurred with some participants that are mentioned in the discussion. Yet, all participants were included in data analysis.

The variables of interest that were measured in this study included: HR, BL, RPE, and the amount of time it takes for the participant to run a one-mile followed by a 400m. Data collection of HR and BL occurred five minutes before both the mile and 400-meter. Along with collection prior to running, HR and BL data were collected immediately, three- and six-minutes post both running bouts. Two other variables were collected as well, the time of completion for the mile and 400-meter bouts, and RPE immediately post-exercise bouts. Figure 1 outlines the research design for this study.

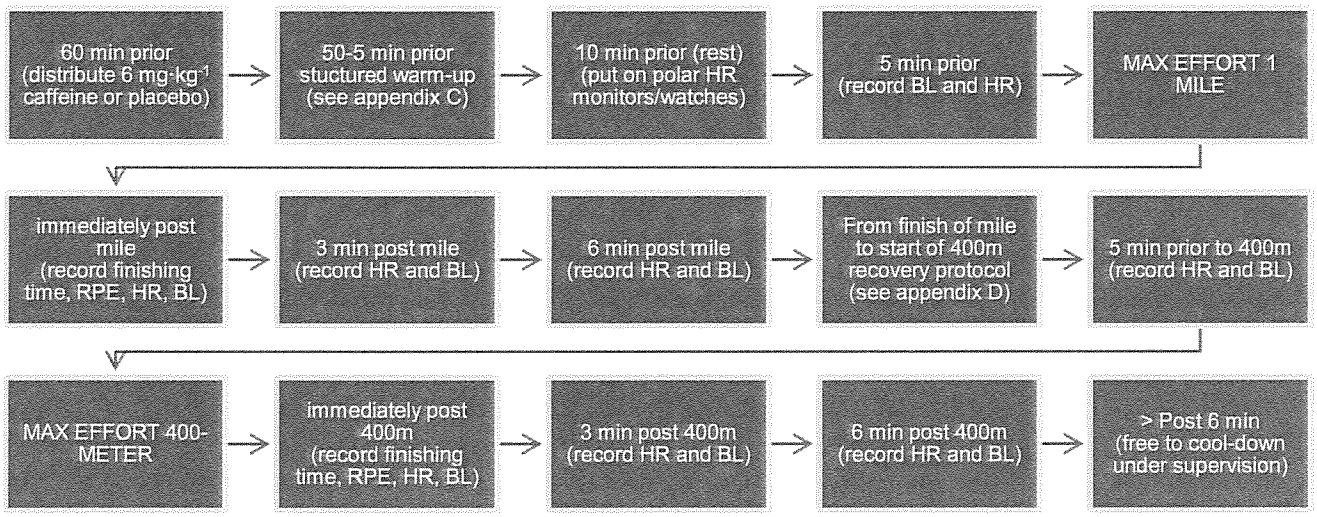

Figure 1. *Flowchart of experimental protocol*

Reliability and Validity

This study's goal was to simulate a race setting, therefore procedures during trial days reflect a high degree of external validity. Having too much control over internal validity may have taken away the direct application to performance (race simulation).

Use of the indoor HATC 200-meter flat track is an NCAA certified facility, ensuring repeatability on any other indoor 200-meter flat track. Use of Polar and Lactate Plus equipment aided the study's HR and BL validity and reliability. Trained and experienced exercise science students at Adams State University aided in gathering data during the trials. The trained student testers were assigned a specific position (eg. gather BL, HR, RPE, record data, etc.) and maintained that position (same tester with same participant) throughout the study to help the study's reliability from trial one to trial two.

All measures of testing were performed at approximately the same time of day. A moderate dose of 6 $mg \cdot kg^{-1}$ anhydrous tablet form was ingested one hour prior to testing for optimal performance. Ganio et al. (2009) stated "performance improvements with

caffeine ingestion are maximized with amounts up to 6 $mg \cdot kg^{-1}$". Distribution one hour prior to testing is most beneficial since caffeine's peak absorption is around 60 minutes (Goldstein et al., 2010). HR was tracked via Polar heart rate monitors to determine the intensity of the participant's trials. BL was gathered via Lactate Plus analyzer. BL is one of the best indicators of a workout's intensity and an athlete's ability to recover. The rapid accumulation of H^+ will directly correlate with a muscle's ability to contract therefore limiting exercise performance (Powers & Howley, 2012).

Also, there was increased reliability with the use of trained NCAA mid-distance athletes as compared to use of untrained participants. Trained individuals are well familiarized with racing or testing scenarios throughout their careers. The same pre-race/test instructions were used for both genders during both trials. According to Bruce et al. (2000) trained individuals have genetic endowment, training history, and training programs making them more likely to perform reliably in a performance task.

Data Analysis

The independent variable for this study is the distribution of caffeine or placebo 60 minutes prior to the mile. The dependent variables are the participants' finishing times in the mile and 400-meter bouts, and HR/BL levels gathered 5 min prior to each running bout as well as immediately, three, and six minutes post each running bout.

Use of paired samples T-tests were used to determine statistical significance between placebo vs. caffeinated trials. With the focus on the difference between caffeinated and placebo trials, variables were tested independently against one another. Shapiro-Wilk and Kolmogorov-Smirnov tests were then used to test normality of the data. The variables

found to be not statistically normal were then analyzed via Related-Samples Wilcoxon Signed Rank Test (nonparametric test).

CHAPTER 4: Results

A total of 12 Adams State University mid-distance athletes completed this study (N=6 males, N=6 females). Subject characteristics were the following (mean ± SD): males: weight 63.7 ± 11.5 kg, age 20.5 ± 2.5 years, mileage per week 90 ± 20 miles, personal best mile (sea-level) 4:23 ± 13 seconds; and for the females: weight 52.9 ± 6.2 kg, age 20.5 ± 1.5 years, mileage per week 62.5 ± 12.5 miles, personal best mile (sea-level) 5:13.5 ± 1.5 seconds. Caffeine consumption for the participants can be found in Tables 1 and 2.

All data analysis was performed using the SPSS Statistics Version 22 program from 2013. Significance was set at $p < .05$ for all variables of analysis. After reviewing the statistical data, two variables out of eighteen were found to be significant, one per gender. Using paired samples t-tests, the male participants' immediate post 400-meter HR placebo (PCB) vs. male immediate post 400-meter HR caffeine (CAF) was found to be significant, $t(5) = -2.931$, $p < .05$ (see Table 3). No other variables for the male participants were found to be significant, however 3 minutes post-mile HR PCB vs. 3 minutes post-mile HR CAF trended towards significance, $t(5) = -.903$, $p = .057$. For the female participants, using the same paired samples t-tests, statistical significance was found in the 5 minutes pre-mile BL PCB vs. 5 minutes pre-mile BL CAF, $t(5) = -3.291$, $p < .05$ (see Table 4).

All other variables were found to be statistically insignificant ($p > .05$) when comparing caffeine and placebo trials, for both men and women (displayed in Tables 5 & 6). Means and standard deviations for all participants are represented in Tables 7 (men) and 8 (women). In order to check for normality of the data, the Shapiro-Wilk and Kolmogorov-Smirnov tests were used. Those variables found statistically not normal were

run through the Related-Samples Wilcoxon Signed Rank Test (nonparametric test) (see Tables 9 & 10).

The males averaged 4:38 during their PCB one-mile and 56.67 seconds in their PCB 400-meter trial. During the CAF trials the males averaged 4:37 in the mile and 55.71 seconds in the 400-meter. The women averaged 5:41 during the PCB one-mile and 65.96 seconds during the PCB 400-meter. For the CAF trials, the female participants averaged 5:46 for the one-mile and 65.73 seconds for the 400-meter trial. Tables 11 and 12 indicate the participants' individual PCB vs. CAF times for each distance; however none were found to be statistically different. Tables 11 and 12 also reveal the average overall time for each distance and each treatment. CAF trials resulted in faster overall times compared to placebo trials for all distances except the women's mile times; however they were not statistically significant.

Table 1. *Average male participant caffeine consumption per/week.*

Average Consumption Per/Week	**0**	**1-2**	**3-4**	**5-6**
Number of Participants	2	1	3	-

Note: *Participants were asked how many days they consume CAF. Specific amounts (mg/kg) consumed were not determined.*

Table 2. *Average female participant caffeine consumption per/week.*

Average Consumption Per/Week	**0**	**1-2**	**3-4**	**5-6**
Number of Participants	-	2	1	3

Note: *Participants were asked how many days they consume CAF. Specific amounts (mg/kg) consumed were not determined.*

Table 3. *Comparison of male HR means between PCB and CAF immediately post 400-meter bouts.*

Variable	**Mean (bpm)**	**Std. Deviation**
Immediate Post-400-meter HR PCB	180.00	6.54
Immediate Post-400-meter HR CAF	185.83	6.94

Table 4. *Comparison of female BL means between PCB and CAF 5 minutes pre-mile.*

Variable	**Mean (mm/L)**	**Std. Deviation**
5 min pre-mile BL PCB	1.5	.45
5 min pre-mile BL CAF	2.4	1.12

Note: *This is an indication of resting lactate levels prior to one-mile bout.*

Table 5. *Paired samples t-test statistical analysis between male PCB and CAF variables.*

Variable	t-statistic (t)	Degrees of Freedom (df)	Signifiance (p)
5 min pre-mile HR placebo vs. 5 min pre-mile HR caffeine	-.92	5	.40
5 min pre-mile BL placebo vs. 5 min pre-mile BL caffeine	-1.88	5	.11
Mile Time placebo vs. Mile Time caffeine	.56	5	.59
Immediate post-mile HR placebo vs. Immediate post-mile HR caffeine	.00	5	1.00
Immediate post-mile BL placebo vs. Immediate post-mile BL caffeine	-.90	5	.40
*3 min post-mile HR placebo vs. 3 min post-mile HR caffeine	-2.46	5	.05
3 min post-mile BL placebo vs. 3 min post-mile BL caffeine	.20	5	.84
6 min post-mile HR placebo vs. 6 min post-mile HR caffeine	-.38	5	.71
6 min post-mile BL placebo vs. 6 min post-mile BL caffeine	-.08	5	.93
5 min pre-400 HR placebo vs. 5 min pre-400 HR caffeine	-.97	5	.37
5 min pre-400 BL placebo vs. 5 min pre-400 BL caffeine	-.08	5	.93
400 Time placebo vs. 400 Time caffeine	1.27	5	.25
**Immediate post-400 HR placebo vs. Immediate post-400 HR caffeine	-2.93	5	.03
Immediate post-400 BL placebo vs. Immediate post-400 BL caffeine	-.13	5	.89
3 min post-400 HR placebo vs. 3 min post-400 HR caffeine	-1.42	5	.21
3 min post-400 BL placebo vs. 3 min post-400 BL caffeine	.37	5	.72
6 min post-400 HR placebo vs. 6 min post-400 HR caffeine	-.56	5	.59
6 min post-400 BL placebo vs. 6 min post-400 BL caffeine	-.16	5	.87

Note: *All variables for male participants found to be statistically insignificant other than those marked with a (**) and those trending with a (*).*

Table 6. *Paired samples t-test statistical analysis between female PCB and CAF variables.*

Variable	t-statistic (t)	Degrees of Freedom (df)	Significance (p)
5 min pre-mile HR placebo vs. 5 min pre-mile HR caffeine	.96	5	.37
**5 min pre-mile BL placebo vs. 5 min pre-mile BL caffeine	-3.29	5	.02
Mile Time placebo vs. Mile Time caffeine	-1.23	5	.27
Immediate post-mile HR placebo vs. Immediate post-mile HR caffeine	.96	5	.37
Immediate post-mile BL placebo vs. Immediate post-mile BL caffeine	.25	5	.81
3 min post-mile HR placebo vs. 3 min post-mile HR caffeine	.94	5	.38
3 min post-mile BL placebo vs. 3 min post-mile BL caffeine	-1.72	5	.14
6 min post-mile HR placebo vs. 6 min post-mile HR caffeine	.73	5	.49
6 min post-mile BL placebo vs. 6 min post-mile BL caffeine	1.09	5	.32
5 min pre-400 HR placebo vs. 5 min pre-400 HR caffeine	-.55	5	.60
5 min pre-400 BL placebo vs. 5 min pre-400 BL caffeine	1.34	5	.23
400 Time placebo vs. 400 Time caffeine	.50	5	.63
Immediate post-400 HR placebo vs. Immediate post-400 HR caffeine	.69	5	.51
Immediate post-400 BL placebo vs. Immediate post-400 BL caffeine	.53	5	.61
3 min post-400 HR placebo vs. 3 min post-400 HR caffeine	.20	5	.84
3 min post-400 BL placebo vs. 3 min post-400 BL caffeine	-.84	5	.43
6 min post-400 HR placebo vs. 6 min post-400 HR caffeine	1.17	5	.29
6 min post-400 BL placebo vs. 6 min post-400 BL caffeine	-1.02	5	.35

Note: *All variables for female participants found to be statistically insignificant other than those marked with a (**).*

Table 7. *Male participant means and standard deviations of all variables.*

Variable	Mean	Std. Deviation
5 min pre-mile HR placebo (bpm)	90.17	10.04
5 min pre-mile HR caffeine (bpm)	94.83	5.45
5 min pre-mile BL placebo (mmol/L)	1.46	.68
5 min pre-mile BL Caffeine (mmol/L)	3.76	2.41
Mile Time placebo (sec)	278.00	8.76
Mile Time caffeine (sec)	276.50	6.02
Immediate post-mile HR placebo (bpm)	184.67	5.35
Immediate post-mile HR caffeine (bpm)	184.67	4.17
Immediate post-mile BL placebo (mmol/L)	10.06	1.77
Immediate post-mile BL caffeine (mmol/L)	11.63	3.89
3 min post-mile HR placebo (bpm)	107.17	7.13
3 min post-mile HR caffeine (bpm)	115.67	7.17
3 min post-mile BL placebo (mmol/L)	12.40	5.20
3 min post-mile BL caffeine (mmol/L)	11.83	2.52
6 min post-mile HR placebo (bpm)	106.50	7.81
6 min post-mile HR caffeine (bpm)	108.33	12.75
6 min post-mile BL placebo (mmol/L)	10.80	2.55
6 min post-mile BL caffeine (mmol/L)	10.90	1.16
5 min pre-400 HR placebo (bpm)	106.00	4.05
5 min pre-400 HR caffeine (bpm)	110.50	10.42
5 min pre-400 BL placebo (mmol/L)	4.51	3.26
5 min pre-400 BL caffeine (mmol/L)	4.66	2.74
400 Time placebo (sec)	56.67	2.55
400 Time caffeine (sec)	55.70	.99
Immediate post-400 HR placebo (bpm)	180.00	6.54
Immediate post-400 HR caffeine (bpm)	185.83	6.94
Immediate post-400 BL placebo (mmol/L)	10.70	2.21
Immediate post-400 BL caffeine (mmol/L)	10.80	1.87
3 min post-400 HR placebo (bpm)	110.67	4.80
3 min post-400 HR caffeine (bpm)	115.83	10.20
3 min post-400 BL placebo (mmol/L)	13.05	5.25
3 min post-400 BL caffeine (mmol/L)	12.23	1.21
6 min post-400 HR placebo (bpm)	108.17	7.08
6 min post-400 HR caffeine (bpm)	110.17	8.11
6 min post-400 BL placebo (mmol/L)	11.78	3.01
6 min post-400 BL caffeine (mmol/L)	12.03	1.77

Table 8. *Female participant means and standard deviations of all variables.*

Variable	Mean	Std. Deviation
5 min pre-mile HR placebo (bpm)	103.00	15.44
5 min pre-mile HRcaffeine (bpm)	96.50	22.59
5 min pre-mile BL placebo (mmol/L)	1.50	.45
5 min pre-mile BL Caffeine (mmol/L)	2.43	1.12
Mile Time placebo (sec)	341.33	11.43
Mile Time caffeine (sec)	345.83	9.10
Immediate post-mile HR placebo (bpm)	185.67	6.18
Immediate post-mile HR caffeine (bpm)	176.67	23.91
Immediate post-mile BL placebo (mmol/L)	12.55	3.01
Immediate post-mile BL caffeine (mmol/L)	12.10	1.57
3 min post-mile HR placebo (bpm)	127.67	4.36
3 min post-mile HR caffeine (bpm)	123.67	11.43
3 min post-mile BL placebo (mmol/L)	11.95	.85
3 min post-mile BL caffeine (mmol/L)	13.93	3.27
6 min post-mile HR placebo (bpm)	124.17	4.62
6 min post-mile HR caffeine (bpm)	122.00	7.56
6 min post-mile BL placebo (mmol/L)	11.58	.94
6 min post-mile BL caffeine (mmol/L)	10.65	2.02
5 min pre-400 HR placebo (bpm)	124.50	6.92
5 min pre-400 HR caffeine (bpm)	126.83	10.45
5 min pre-400 BL placebo (mmol/L)	5.51	2.94
5 min pre-400 BL caffeine (mmol/L)	3.55	1.53
400 Time placebo (sec)	65.95	3.09
400 Time caffeine (sec)	65.73	2.76
Immediate post-400 HR placebo (bpm)	182.83	6.43
Immediate post-400 HR caffeine (bpm)	181.83	7.88
Immediate post-400 BL placebo (mmol/L)	11.88	2.95
Immediate post-400 BL caffeine (mmol/L)	11.48	2.39
3 min post-400 HR placebo (bpm)	126.17	6.11
3 min post-400 HR caffeine (bpm)	125.00	12.99
3 min post-400 BL placebo (mmol/L)	13.65	1.91
3 min post-400 BL caffeine (mmol/L)	15.11	3.47
6 min post-400 HR placebo (bpm)	123.33	3.32
6 min post-400 HR caffeine (bpm)	120.00	9.71
6 min post-400 BL placebo (mmol/L)	12.51	1.79
6 min post-400 BL caffeine (mmol/L)	13.78	2.13

Table 9. Males' N*onparametric Related-Samples Wilcoxon Signed Rank Test.*

Variable	Test statistic (z)	Sample Size (N)	Significance (p)
Immediate post-mile HR PCB vs. Immediate post-mile HR CAF	-.31	1	.75
3 min post-mile BL PCB vs. 3 min post-mile BL CAF	.52	1	.60
6 min post-mile BL PCB vs. 6 min post-mile BL CAF	.10	1	.91
3 min post-400 BL PCB vs. 3 min post-400 BL CAF	.31	1	.75

Table 10. *Females' Nonparametric Related-Samples Wilcoxon Signed Rank Test.*

Variable	Test statistic (z)	Sample Size (N)	Significance (p)
Immediate post-mile HR PCB vs. Immediate post-mile HR CAF	.67	1	.49
3 min post-400 BL PCB vs. 3 min post-400 BL CAF	.73	1	.46
5 min pre-mile HR PCB vs. 5 min pre-mile HR CAF	-.94	1	.34
5 min pre-400 BL PCB vs. 5 min pre-400 BL CAF	-1.15	1	.24

Table 11. *Male participant PCB vs. CAF mile and 400-meter times.*

Participant	PCB Mile	CAF Mile	PCB 400-Meter	CAF 400-Meter
1	4:32	4:28	55.53	55.62
2	4:47	4:45	54.18	54.13
3	4:51	4:39	61.33	56.73
4	4:33	4:40	55.83	56.10
5	4:30	4:33	55.43	55.06
6	4:35	4:34	57.72	56.61
Averages	**4 :38**	**4 :37**	**56.67 s**	**55.70 s**
Std. Deviation	**± 8.76 s**	**± 6.02 s**	**± 2.55 s**	**± .99 s**

Table 12. *Female participant PCB vs. CAF mile and 400-meter times.*

Participant	PCB Mile	CAF Mile	PCB 400-Meter	CAF 400-Meter
1	5 :35	5 :50	64.06	65.12
2	5 :58	5 :55	68.88	69.30
3	5 :31	5 :30	67.48	65.97
4	5 :32	5 :41	60.6	61.12
5	5 :53	5 :47	66.72	65.27
6	5 :39	5 :52	68.00	67.62
Averages	**5 :41**	**5 :46**	**65.95 s**	**65.73 s**
Std. Deviation	**± 11.43 s**	**± 9.10 s**	**± 3.09 s**	**± 2.76 s**

CHAPTER 5: Discussion

The purpose of this study was to determine if a dose of 6 $mg \cdot kg^{-1}$ caffeine would benefit multiple bout mid-distance performance (time), and to determine caffeine's effects on heart rate and blood lactate recovery.

Though only two variables measured were found to be statistically significant, much can be taken from the results of this field study. Considering this study was conducted in a field setting (indoor track) to replicate actual meet and championship track racing, practical application of the data indicates caffeine may be beneficial for performance (time). To the researcher's knowledge, this is the first caffeine study conducted on multiple-bout mid-distance performance in a field setting (indoor track).

This chapter includes a discussion of the results, and suggestions for future research of each component of the original hypotheses.

Hypothesis 1: Collegiate mid-distance athletes would see improvement in mile performance through use of caffeine ingestion.

For the male and female participants, hypothesis #1 must be rejected, thus the null hypothesis must be accepted for all participants of each gender.

The results indicated in Table 11 reveal average mile times for the men improved by one second in the caffeinated compared to the placebo trials. Though one second was not seen as statistically significant (p=.595), one second in a championship race is more than enough to beat an opponent. Four out of six male participants performed faster mile times during the caffeinated trials compared to their placebo trials. The four male participants that had faster caffeine mile times performed an average of 4.75 seconds faster than their

placebo mile times. This result is similar to Wiles et al. (1992), who showed faster 1,500 meter (similar to mile distance, 1,609 meters) times by 4.2 seconds in caffeine trials compared to placebo trials. However, Wiles et al. (1992) performed their testing within a laboratory setting on a treadmill. Perhaps caffeine is a viable method to benefit the middle-distance event area, yet more research should be conducted within the field rather than in a laboratory. The two males within this field study that performed slower during the caffeine trials ran an average of 5 seconds faster during their placebo mile bout. These participants may have ran faster in the placebo trials for multiple reasons, such as familiarity of the test (both received CAF during trial 1), their week of training prior to the trial (fatigue), and temperature within the indoor track facility (trial 1 was warmer than trial 2). Nonetheless the average of all male participants resulted in caffeine improving overall mile performance practically; it was just not statistically significant.

For the female participants, Table 12 reveals average mile times did not show an increase in performance during the caffeinated trials. Contrasting to the male participants, the females performed an average of 5 seconds faster in the placebo trials compared to caffeine trials. Of the female participants, 50% of them performed faster when given the caffeine treatment. Those that performed faster with caffeine ran an average of 3.3 seconds faster than their placebo trials. Those that performed slower with caffeine in their system ran an average of 12.3 seconds slower for caffeine trials compared to placebo trials. This large discrepancy for the women may be due to a few reasons.

There were three female participants that had a complication arise from trial one to trial two. One of the participants had not ran a maximal effort mile at altitude before; therefore her first trial (caffeine) was not deemed accurate by the researcher. With a lower

pO_2 at altitude, the effects of starting out too quickly in a race leads to a greater onset of oxygen deficit, therefore the athlete is more likely to fatigue early in the race. During trial two (placebo) the female participant now had familiarity of the mile at altitude and ran a smarter more efficient (better paced) race, thus running faster overall. Another female had lower extremity pain which forced her to wear training shoes rather than racing spikes. During the first trial (placebo) the participant ran in racing spikes, whereas during the second trial (caffeine) she chose to wear training shoes which are heavier and provide less traction compared to spikes. Had she been pain free for the second trial and worn spikes, her results may have been different. Lastly, another female had personal physiological issues during trial 2 (caffeine) which interfered with her ability to push her body to a maximal effort mile. Unfortunately some of the female participants had complications arise, unrelated to caffeine; thus it is necessary to perform future research with more females.

Mile and 400-meter performance may have been affected by the participant's usual amount of caffeine consumption. Research by Gwacham and Wagner (2012) suggested that caffeine's ergogenic benefits will vary depending if a person is a habitual or non-habitual user of caffeine. The more caffeine an individual typically consumes, the less likely they are going to receive performance benefits (Gwacham and Wagner, 2012). Within this study, the female participants consumed more caffeine weekly compared to the male participants (Table 1 & 2). Thus, the researcher suggests this could be one of the reasons more male participants experienced performance benefits. However, it has been found that implementing a 48-hour caffeine abstinence period will help emphasize caffeine's benefits whether you're a habitual or non-habitual user (Tarnopolsky et al., 1989). Since a 48-hour

abstinence period was incorporated within the conducted study, it cannot be determined if the participants' caffeine tolerance had a negative or positive effect on performance.

Hypothesis 2: Caffeine ingestion would lead to higher levels of lactate production making the 400-meter bout slower compared to placebo. Furthermore, placebo trials would illustrate better lactate recovery compared to caffeinated trials.

For the male participants there was a slightly higher (but insignificant, $p > .05$) blood lactate average in the body immediately post-mile caffeine trials (11.63 $mmol \cdot L^{-1}$) compared to the placebo (10.06 $mmol \cdot L^{-1}$).

Table 13. *Males' BL recovery post one-mile.*

Time When BL Was Gathered	BL Levels (mmol/L)	
	CAF	PCB
Immediately post one-mile	11.63 ± 3.89	10.06 ± 1.77
6 min post one-mile	10.90 ± 1.16	10.80 ± 2.55
5 min pre 400-meter	4.66 ± 2.74	4.51 ± 3.26

With respect to the hypothesis, it was found to be rejected due to the lack of statistical significance, therefore the null hypothesis must be accepted. Six minutes post-mile the blood lactate levels were insignificant (CAF = 10.90 $mmol \cdot L^{-1}$ vs. PCB = 10.80 $mmol \cdot L^{-1}$), as well as blood lactate five minutes prior to 400-meter bout (CAF = 4.66 $mmol \cdot L^{-1}$ vs. PCB = 4.51 $mmol \cdot L^{-1}$) (Table 13). It appears that for the males, whether given CAF or PCB, BL recovery after the one-mile bout is similar between treatments. Similar to the mile results for the male participants, the average 400-meter times for the caffeinated trials (55.71 seconds) were practically faster than the placebo trials (56.67 seconds), however statistically insignificant ($p > .05$) (Table 11). In a practical sense, a difference of .96 seconds is quite substantial in a 400-meter run. In a race setting, having the ability to take

off .96 seconds in a 400-meter run would be similar to taking off multiple seconds from a mile. Even though BL levels in recovery were not found to be different between CAF and PCB, 400-meter times appeared to have improved during the CAF trials.

The female's 400-meter outcome was similar to the male participants. The female participants ran faster during the caffeinated (65.73 seconds) 400-meters compared to the placebo (65.96 seconds) trials (Table 12). Statistically, a difference of .23 seconds once again is not considered to be significant. However, practical application to the sport of track and field would say differently. In track and field, the shorter a race is, the more significant fractions of a second become; thus improvement by almost a quarter of a second in a 400-meter run is substantial. Blood lactate levels on the other hand did not show a similar pattern to the men's. Immediate post-mile, the average blood lactate levels were not significantly different (CAF = 12.10 mmol·L^{-1} vs. PCB = 12.55 mmol·L^{-1}, $p > .05$).

Table 14. *Females' BL recovery post one-mile.*

Time When BL Was Gathered	BL Levels (mmol/L)	
	CAF	PCB
Immediately post one-mile	12.10 ± 1.57	12.55 ± 3.01
6 min post one-mile	10.65 ± 2.02	11.58 ± .94
5 min pre 400-meter	3.55 ± 1.53	5.51 ± 2.94

However, the average blood lactate levels five minutes pre-400-meter run had more of a difference, yet no statistical significance (CAF = 3.55 mmol·L^{-1} vs. PCB = 5.51 mmol·L^{-1}, $p > .05$) (Table 14). Though the lactate levels were not statistically significant, the higher PCB blood lactate levels five minutes pre-400-meter bout may have negatively affected running performance. For the women, they appeared to recover quicker during the caffeinated treatment compared to the placebo; thus starting the 400-meter bouts with less blood

lactate in their bodies. This should delay the onset of fatigue during the 400-meter run, which may be a contributing factor to the faster women's 400-meter times in the caffeinated trials compared to the placebo trials.

Similarly, the male and female participants saw a decrease in blood lactate levels from immediate post-mile vs. five minutes pre-400-meter run (25 minutes elapsed time) (Tables 13 & 14). Therefore, a light active recovery jog between multiple bouts may help improve subsequent performance for both caffeine and placebo trials. Menzies et al. (2010) performed a study where ten participants performed a five-minute treadmill run at 90% VO_2max, followed by active recovery at various percentages (0, 40, 60, 80, 100) of their lactate threshold. Their results indicated active recovery at a higher percentage of one's lactate threshold provides better lactate clearance compared to recovering at lower percentages (Menzies et al., 2010). Therefore jogging at a quicker recovery pace will allow your body to buffer lactate faster compared to a slow jog recovery. According to Menzies et al. (2010) performing active recovery after a strenuous aerobic exercise bout is more beneficial to lactate clearance compared to passive recovery. Regardless of the percentage their participants recovered at, they found all active recovery trials more beneficial than passive recovery. The blood lactate recovery rates in the current field study varied between the men and women and the mile and 400-meter runs. Analysis of the data did not indicate statistical significance, which is in contrast to Bridge and Jones (2006) who found blood lactate levels to be significantly higher three minutes post 8-km performance for the caffeine compared to the placebo. It may be possible that longer, more aerobic events result in higher lactate accumulation post-maximal effort. Therefore caffeine supplementation for shorter mid-distance events may see less of a negative lactate accumulation effect

compared to longer events. A longer event (5-10 km race) performed at race effort will often continue to produce higher blood lactate amounts post-race compared to during the race (Bridge and Jones, 2006). Similar to Bridge and Jones (2006), Bell et al. (2001) also found caffeine to contribute to higher post-exercise blood lactate levels compared to the placebo. However, Bell et al. (2001) was also another longer more aerobic event (10-km). More caffeine supplementation research appears to be needed in the middle-distance area to further investigate caffeine's effect on blood lactate recovery.

Hypothesis 3: Heart rate levels would not reveal a significant difference when comparing the two treatments.

Immediate post-400-meter heart rate for male participants was one of the only variables to be found statistically significant ($p = .033$). Placebo heart rate average 180 bpm (SD: 180 ± 6.54 bpm) was slightly lower than the average caffeine trial heart rates 185 bpm (SD: 185 ± 6.94 bpm) (Table 3). Overall, the male participant caffeine trial data revealed a higher mean heart rate compared to the placebo. Though heart rate levels were slightly more elevated for caffeine trials, the participants' perception of effort (RPE) was not significantly different.

Table 15. *Immediate post-bout pain perception readings via RPE scale.*

Gender	PCB Mile	CAF Mile	PCB 400-Meter	CAF 400-Meter
Male	17.17 ± 1.47	18.17 ± .75	18.67 ± 1.21	19.00 ± .63
Female	17.83 ± .98	16.67 ± 2.50	17.33 ± 2.51	17.67 ± 1.37

Similar results were shown in Bell et al. (2001) and Glaister et al. (2008) where caffeine did not affect sensation of effort during performance. Similar to caffeine's effect on blood lactate, caffeine did not negatively affect heart rate recovery. Average heart rate recovery

for the male participants' post-mile bout was 41.4% (CAF) vs. 42.4% (PCB), meaning that during the six-minute post-mile data collection, heart rates recovered from 184 to 108 bpm (CAF) and 184 to 106 bpm (PCB). For the 400-meter bouts, heart rate recovery was 40.5% (CAF) vs. 40% (PCB), or 185 to 110 bpm (CAF) and 180 to 108 bpm (PCB). Therefore caffeine does not appear to negatively affect post-exercise heart rate recovery for the males in this study, as most of the data supports the hypothesis.

For the female participants, the hypothesis can be accepted. Lack of statistical significance may be from two of the female participants not being able to give as maximal of an effort for their second trial (CAF) due to reasons discussed earlier. For the female participants, there appears to be more of a difference between heart rate recovery when comparing CAF and PCB, yet still not statistically significant. Average heart rate recovery for the female participants' post-mile was 30.7% (CAF) vs. 33% (PCB), or a heart rate recovery of 176 to 122 bpm (CAF) vs. 185 to 124 bpm (PCB). For the 400-meter bouts, heart rate recovery was 33.8% (CAF) vs. 32.4% (PCB), or 181 to 120 bpm (CAF) vs. 182 to 123 bpm (PCB). With the female participants, there appears to be more inconsistencies in the data compared to the men. The researcher believes this may be a result from the complications discussed earlier with half of the female population used. Data was not consistent enough to determine the effects caffeine had on heart rate. Heart rate averages may be skewed for the female participants.

Conclusion of Discussion

After examination of the results, caffeine showed some practical signs of being a viable method for increasing multiple-bout mid-distance performance. Statistical significance, however, was not very prominent within this study. Lack of statistical

significance may be due to the study being conducted in a field setting (not as controlled as a laboratory setting) and using a small sample size (six per gender). Though statistically there was not the evidence, good practical application is more prominent. With several of the participants performing at a higher level when consuming 6 $mg \cdot kg^{-1}$ caffeine, it may be beneficial to continue more research within this area. Blood lactate and heart rate recovery did not appear to be negatively affected enough to conclude caffeine is deemed bad for multiple-bout mid-distance performance activity. For shorter, mid-distance bouts, there was no differentiation of pain perception (based on RPE) between the two treatments. Due to the male participants having a 6/6 success rate for no complications from trial one to trial two, their data was more valid and reliable compared to the women's data which had a 3/6 success rate. Future research is deemed necessary to develop a firm conclusion of caffeine's effects on multiple-bout mid-distance performance and recovery, in both men and women.

CHAPTER 6 : Summary & Conclusion

Summary of Major Findings

The purpose of this study was to determine if caffeine supplementation had a positive effect on the overall performance in Division II male and female collegiate mid-distance athletes. Overall performance was ultimately determined by the participants' multiple-bout one-mile and 400-meter times on a 200-meter indoor track field setting. The secondary purpose of this study was to analyze heart rate and blood lactate levels during recovery after both bouts.

Overall running performance (time) after ingestion of 6 $mg \cdot kg^{-1}$ caffeine was found to be statistically insignificant, but practically improved in 7 of 12 participants (4 of 6 males and 3 of 6 females) compared to placebo treatment. The increases in performance (reduced time) were found in both the mile and 400-meter bouts. The male participants' immediate post 400-meter HR placebo vs. male immediate post-400-meter HR caffeine was found to be significant, $t(5) = -2.931$, $p < .05$. Though this was the only variable found to be statistically significant, male participant heart rate levels were found to be slightly more elevated in the caffeinated vs. the placebo trials. Often heart rate corresponds with perception of pain, however in this study, pain perception (RPE) was not found to be significantly different between treatments.

Recommendations and Future Research

This study was unique in the fact that it was conducted in a field setting (indoor 200-meter track). Working with middle distance runners in the middle of season is great for practicality, however it may be beneficial to have full control over the participants'

training weeks. Since the athletes could not stop their current training regimen, their weekly workout may have had an effect on their trials. The researcher recommends conducting this study again with more participants and different distances. Experimenting with different distances would be beneficial to help determine when caffeine is most beneficial for enhancing sports performance. For example, doing a multiple bout protocol with a one-mile and an 800-meter run, or a 3,000-meter and a one-mile, etc. as these are common meet doubles for track athletes. Another aspect the researcher recommends is having more control over their training, diet, and sleep. Rather than encouraging the participants to keep a food log and replicate it to the best of their ability from trial one to trial two, it would be beneficial to have all participants eat the same meals together. This would help ensure similar macronutrient intake prior to the trials. Carbohydrate levels in particular should be standardized due to their effect on mid-distance/distance performance and lactate accumulation. After the data analysis for this study, the researcher wouldn't recommend gathering so many variables at so many different time segments. The researcher recommends gathering only immediate and six minutes post-bout blood lactate and heart rate variables. The pre-bout data gathering and three minutes post-bout data gathering seems to be excess data for determining recovery. The researcher suggests the immediate and six minutes post-bout gathering would be sufficient enough for determining recovery variables.

Practical Applications

From this current study's results, along with the research reviewed for this study, the researcher believes it is beneficial to consume a low to moderate dose of caffeine (2-6 $mg \cdot kg^{-1}$) for aerobic exercise/sport performance benefit. Mid-distance athletes may

want to experiment with more moderate (5-6 $mg \cdot kg^{-1}$) doses of caffeine to increase CNS stimulation and neuromuscular function due to the more explosive nature of their events. Caffeine supplementation may not be beneficial for everyone. Caffeine does have minor side effects which can cause irritability, gastrointestinal issues, jitteriness, etc. Thus different amounts of caffeine may work better for some individuals compared to others. The researcher recommends starting with smaller doses to determine where the athlete's body benefits from caffeine, and where their body is negatively affected by caffeine. Therefore, personal trial and error test runs should be performed at practice sessions before bringing caffeine into competition.

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APPENDIX A

One Mile Field Study Questionnaire

Please fill out/circle the following to the best of your knowledge:

1. Age..... _____
2. Weight(pounds).....____
3. How many days/week do you consume caffeine?.....0 1-2 3-4 5-7
   A. What form or forms do you consume? (coffee, pop, energy drink, pre-workout, etc.)
   _____
   B. How much do you consume?.....____
4. Approximate running Milage per/week.....____
5. How many years have you been competing in track and field? .....____ years
6. What is your personal best in the mile? .....____min ____seconds

Health

1. Do you have any current health restrictions that may inhibit your ability to perform a maximal one mile test? **YES / NO** (If YES, list/describe your restrictions)
   _____
   _____
   _____
2. Have you ever fainted after performing a maximal test or race? **YES / NO** (If YES, what happened?)
   _____
   _____
   _____
3. Do you have any allergies? **YES / NO** (If YES, what are you allergic to?)
   _____
   _____
4. Do you currently take any medications or dietary supplements? (If YES, list all)
   _____
5. Have you ever experienced negative symptoms from caffeine use? **YES / NO**
   Circle symptoms you've experienced: Headache - Heart pain - Jitteriness - Dizziness - Other _____
6. If chosen, will you be willing to participate in the following study? The study analyzes the effects of caffeine ingestion on a maximal one mile race/test. There will be two separate races/tests separated by a one week recovery period. **YES / NO**

APPENDIX B

Participant Consent Form & IRB Approval Form

Appendix B

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT ADAMS STATE UNIVERSITY

The Effects of Caffeine Supplementation in Division II Track Athletes During a Multiple-Bout Mid-Distance Performance

You are being asked to participate in a research study involving caffeine. Caffeine is one of the world's most commonly used stimulants. Commonly associated with increased endurance performance, caffeine is considered an ergogenic aid. This experiment may help provide evidence for caffeine's effects on mid-distance performance. The purpose of this study is to determine if caffeine supplementation will benefit mid-distance performance in a repeated bout format to simulate doubling at track meets. You have been identified as a possible subject because you currently are a mid-distance track athlete at Adams State University. Participation is voluntary. If you agree to partake in the following study, you will be asked to perform a maximal one-mile test followed by a maximal 400-meter bout. You will be performing this test on two separate occasions separated by one week recovery. Sixty minutes prior to testing you will consume either caffeine or a placebo in anhydrous form.

Procedures:

Due to the nature of this study, you will be asked to refrain from caffeine intake 48 hours prior to test day (coffee, tea, pop, energy drinks, chocolate, etc). You also must refrain from any food ingestion 2 hours prior to each trial. Additionally, you will be asked to log your dietary intake 24 hours prior to each test day.

1. Height and weight will be taken at the Human Performance Lab located in East Campus.
2. You will be randomly assigned a dose 6 $mg \cdot kg^{-1}$ of caffeine or placebo (sugar pill) 60 min prior to mile start which may influence your racing ability.
3. A specific protocol for pre-testing warm-up will be given.
4. You will be asked to wear a Polar heart rate monitor strap and watch 10 min prior to mile start which will monitor HR throughout the experiment.
5. Blood lactate via finger prick and heart rate will be recorded five minutes prior to mile start.
6. You will then run a max effort one-mile simulated in the indoor high altitude training center (the Bubble) against other participants of the same gender.
7. Immediately, three minutes, and six minutes post one-mile your heart rate, rate of perceived exertion, and blood lactate will be recorded.

8. A specific recovery period protocol between mile and 400-meter running bouts will be given.
9. Blood lactate and heart rate will be recorded five minutes prior to 400-meter start.
10. You will run a max effort 400-meter bout in the indoor high altitude training center (the Bubble) against other participants of the same gender.
11. Immediately after your finish, the same post-race variables mentioned earlier will be taken again.

Duration of Participation:
All data collection for the study will take place within a two week time frame. You will be asked to report to the Bubble under two occasions, trial one and trial two (eg. Saturday to Saturday). Each trial will take around two hours from start to finish and be held at approximately the same time of day and will consist of the procedures explained above. Prior to trial number one, you will be asked to meet in the Human Performance & Physical Education Lab at East campus to gather your weight.

Benefits:
As a participant of this study you will have the chance to see whether supplementation with caffeine helps your personal mid-distance performance. Results will be explained/discussed with you individually to inform you of your personal results. During our personal meeting you will also be given the opportunity to learn about exercise physiology that may help benefit your performance. With the research on multiple bout mid-distance performance and caffeine supplementation being very minimal, data from this study will help gain a better understanding in the specified area.

Risks and Discomforts:
This study requires a maximal double bout effort on the indoor high altitude training center track. After maximal effort running bouts you may be susceptible to discomforts such as dizziness, tight muscles, shortness of breath, soreness, blisters, sickness, headache, etc. Possible side effects from caffeine ingestion include: headache, chest pain, irritability, jitters, bowel movement, and sleep impairment. Blood lactate extraction using the Lactate Plus device may cause slight pain. The device uses a miniature spring loaded lancet which will puncture your fingertip drawing a droplet of blood. Your finger will be squeezed by a researcher in order for the device to gather enough blood. Slight pain from the lancet puncture is very brief, however your fingertips may be faintly tender for 24 hours. By using highly trained collegiate distance athletes, they are familiar to maximal effort bouts. Using a protocol similar to a race scenario, the participants will already have an understanding of the possible discomforts. Thus the proposed study is low risk to the participants.

Confidentiality:
Your information and any data collected throughout the study will be held confidential personally by the lead researcher (Clayton Foster). Data will be held confidential for five years then destroyed by the lead researcher. Adams State University holds the right to use the results from this study for future research purposes. Data will be reported in group means securing anyone from being identified individually. In such cases, participants will be asked to sign a release form freeing evidence gathered throughout the study.

I agree that Adams State University and its employees are not held liable for any possible injuries that may occur during my participation. I hereby agree to release them from any liabilities from or during this research study.

INQUIRIES:
Any questions or concerns regarding this study should be directed to the following.

Primary Researcher:	Clayton Foster	(218)-251-6162	ckfoster@adams.edu
Committee Chair:	Tracey Robinson	(719)-587-7663	trobins@adams.edu
IRB Chair:	Robert Demski	(719)-587-7216	rmdemski@adams.edu

AUTHORIZATION:
I have read the above and understand the benefits, discomforts, inconvenience and risks of this study. I, _____ (printed name of subject), agree to participate in this research. I understand that participation is voluntary and I may deny consent now or withdrawal from the study at any time without penalty. I have received a copy of this consent form for my own records.

Participant Signature: _____ Date: _____

Researcher Signature: Clayton Foster Date: 3/20/15

ADAMS STATE COLLEGE
INSTITUTIONAL REVIEW BOARD
Approved on: 3-16-15
Expires on: 3-16-16

Adams State University

Request To Obtain Approval for the Use of Human Participants

Date: February 17, 2015

To: Rob Demski, IRB Chair

From: Clayton Foster, fosterck@grizzlies.adams.edu

Mailing Address: 106 Pike Ave. #10, Alamosa CO, 81101

Phone: 218-251-6162

Subject: Caffeine Supplementation and Multiple-Bout Mid-Distance Performance

(a) **Responsible Faculty Member:** Tracey Robinson, Ph.D.
Email: tlrobins@adams.edu
Phone: 719-587-7663

(b) **Others in contact with human participants:** Possible HPPE graduate students; Megan Nelson, HPPE visiting professor

(c) **The Title of the Research:** The Effects of Caffeine Supplementation in Division II Track Athletes During A Multiple-Bout Mid-Distance Running Performance (Master's Thesis Research)

(d) **Objectives of the Research:**

A large portion of research previously conducted involves caffeine supplementation and time-to-exhaustion protocols within a laboratory setting. There is minimal research performed in the area of caffeine and mid-distance performance, let alone any involving both mid-distance and multiple-bout running performance. Additionally, performing this study in a field setting (indoor track) allows for better application to sports performance. Athletes are constantly on the lookout to improve their performance.

The purpose of this study is to determine if caffeine supplementation will benefit mid-distance performance in a repeated bout format to simulate doubling at track meets. This will be determined by the participants overall time in the one-mile and 400-meter bouts. Use of the Lactate Plus analyzer will help determine if caffeine raises post-performance lactate levels which in turn may affect the second bout.

By using highly trained collegiate distance athletes, they are familiar to maximal effort bouts. Using a protocol similar to a race scenario, the participants will already have an understanding of the possible discomforts. Thus the proposed study is low risk to the participants.

(e) Methods of Procedure:

The Setting: Testing will take place on the indoor track in the high altitude training center (HATC), also known as the Bubble, at Adams State University in Alamosa, Colorado, at an elevation of 7,544 feet. The Adams State indoor facility will control for any possible environmental factors.

The Participants: Six male and six female collegiate mid-distance track athletes from an elite NCAA Division II University (Adams State University) will be asked to volunteer for testing. They will have a background of 6 ± 3 years racing mid-distance (eg. 800m – 3,000m). Men's training volume will range from 90 ± 15 miles/week and women's training volume will range from 80 ± 15 miles/week. Participants will be selected based on ability to perform a one mile run test and individual health. Men's mile times at altitude will range from 4:27 ± 6 seconds and women's mile times at altitude range from 5:25 ± 10 seconds. Preferably, participants will be similar in mile time performance to better control the results of the study and provide an atmosphere similar to an actual race. Women and men will be tested separately by gender to simulate competition setting. Selecting participants with similar endurance capacities will help control psychological race aspects, such as intimidation and lack of confidence to win. An equal race setting will contribute to increased validity of race results. Participants will not be remunerated for participating in this study.

Instrumentation: Athletes will be tested on a 200-meter indoor NCAA certified polyurethane rubber track surface. The track has metal rails on the inside of lane one to prevent athletes from cutting the corners. A standard Borg scale will be used to measure RPE to determine participant's perception of effort immediately post one-mile and 400-meter bouts. Each participant will wear the T31 Polar transmitter chest strap and watch to gather pre and post testing HR. In order to gather pre and post-trial blood lactate levels, the Lactate Plus analyzer, Nova Biomedical lactate test strips and lancets will be used. Trials will be timed using the ChronoTap – Stopwatch application created by Kodeman Industries.

Research Design: Participants that show interest in participating in the study will be required to sign an informed consent approved by the IRB committee at Adams State University (see appendix B). Each participant who volunteers will be required to complete a questionnaire before they are selected for the study (see appendix A). Participants will be asked about the frequency of caffeine ingestion, personal one mile time, health restrictions, demographics, mileage per week, and willingness to participate. Based on their responses, six participants of each gender will be asked to participate in the study. Health and safety (eg. heart conditions, allergies to caffeine, etc.) is the number one priority for being selected to participate. Along with health and safety, the participant's mile times, weekly

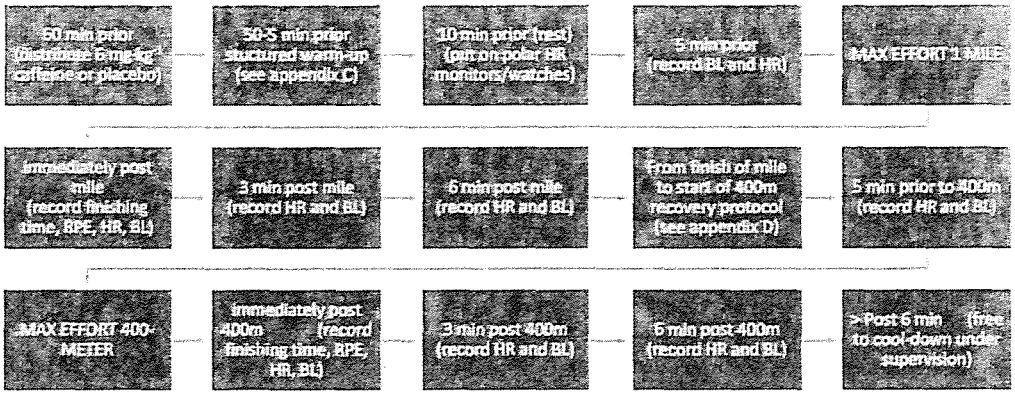
mileage, and frequency of caffeine consumption (preferably non-habitual) will be deciding factors for study admission. The participants that group closest in these categories, especially mile times, will be preferred to participate in the study. Participants not be deceived on their treatment given or the possible outcomes.

A dose of 6 mg·kg^{-1} of caffeine in anhydrous capsule (Maximum Strength Awake/Walgreens) form or placebo (sugar pill that looks and tastes similar) will be distributed to participants 60 minutes prior to testing. The distribution of caffeine or placebo will be overseen by the double-blind personnel to ensure proper ingestion. A randomized double-blind crossover design will be used during this experimental study. All men together and women together (separate trials) will end up doing both conditions. During each trial there will be equal randomization between the participants (3 caffeinated/3 placebo women & 3 caffeinated/3 placebo men). Participants will be running a maximal effort one-mile run, given 30 minutes recovery, and then follow that with a maximal 400-meter run. The study will consist of a total of two experimental trials, with each trial separated by one week of recovery allowing adequate recovery. Participants will all perform the same structured warm-up (see appendix C) and structured recovery period between the mile and 400-meter bout (see appendix D). Prior to each trial, participants will be asked to refrain from ingesting any caffeine for a full 48 hours. They will be required to keep a 24-hour food log prior to each trial to replicate similar diets for each trial. Also, participants must refrain from any food consumption 1-hour prior to caffeine or placebo ingestion.

If there are any incidences of a participant becoming too sick or injured prior to the first trial session, a different individual who filled out the questionnaire will be asked to volunteer in their place. However, if there is an incidence where a participant becomes too sick or injured between trials one and two to continue, their data will be separated from other participants. This process also applies to the chance of a participant not showing up to one of the trials. If any of these scenarios occur, the data discrepancies will be mentioned in the discussion. Participants will not be penalized upon any incident occurring.

The variables of interest that will be measured in this study include: HR, BL, RPE, and the amount of time it takes for the participant to run a one mile followed by a 400m. Data collection of HR and BL will occur five minutes before both the mile and 400 meter. Along with collection prior to running, HR and BL data will be collected immediately, three and six minutes post both running bouts. Two other variables will be collected, the time of completion for the mile and 400-meter bouts, and RPE immediately post exercise bouts. The flowchart of experimental protocol outlines the research design for this study.

Flowchart of Experimental Protocol:



Duration of Participation: All data collection for the study will take place within a two week time frame. You will be asked to report to the Bubble under two occasions, trial one and trial two (eg. Saturday to Saturday). Each trial will take around two hours from start to finish and be held at approximately the same time of day and will consist of the procedures explained above. Prior to trial number one, you will be asked to meet in the Human Performance & Physical Education Lab at East campus to gather your weight.

Benefits: As a participant of this study you will have the chance to see whether supplementation with caffeine helps your personal mid-distance performance. Results will be explained/discussed with you individually to inform you of your personal results. During our personal meeting you will also be given the opportunity to learn about exercise physiology that may help benefit your performance. Performing in this study will also benefit this area of research within exercise science.

Risks: This study requires a maximal double bout effort on the indoor high altitude training center track. After maximal effort running bouts participants may be susceptible to discomforts such as dizziness, tight muscles, shortness of breath, soreness, blisters, sickness, headache, etc. Possible side effects from caffeine include: headache, chest pain, irritability, jitters, bowel movement, and sleep impairment. Blood lactate extraction using the Lactate Plus device may cause slight pain. The device uses a miniature spring loaded lancet which will puncture participant's fingertips drawing a droplet of blood. Participant's fingers will be squeezed by a researcher in order for the device to gather enough blood. Slight pain from the lancet puncture is very brief, however fingertips may be faintly tender

for 24 hours. The proposed study is low risk for the well-trained collegiate distance athletes.

(f) **Protection Measures:** Participation in the study is voluntary. All participants will be fully informed of all study procedures (although they will not know whether they get a placebo or caffeine during the 2 trials), and may withdraw at any time. Participants will also be asked to fill out a questionnaire regarding their health status prior to any testing, and if necessary, have a physician's clearance before participating in the study. All field testing will be conducted within the High Altitude Training Center (the Bubble) at Adams State University. Both trials will be supervised by the leading researcher, Clayton Foster, and a past graduate of Adams State University's exercise science Master's program, Maria Martinez. Clayton and Maria will also be the administrators performing lactate testing for both trials. The other volunteer assistants for the study are graduate or undergraduate exercise science students who have a background in procedures used in this study. Participant's information and any data collected throughout the study will be held confidential by the lead researcher (Clayton Foster). Data will be held confidential for five years then destroyed by the lead researcher. Adams State University holds the right to use the results from this study for future research purposes. Data will be reported in group means securing anyone from being identified individually. In such cases, participants will be asked to sign a release form freeing evidence gathered throughout the study.

(g) **Changes:** If any changes are made to the research I will contact the IRB immediately and fill out the needed paperwork.

(h) **Consent:** Participants will be asked to read over and sign the consent form before any testing commences. The informed consent is attached separately.

Tracy L Robinson 3-19-2015

Name and Signature of Department Chair or Appropriate Person Date

Robert Demski Robert Demski 3-16-15

Name and Signature of IRB Chair Date

APPENDIX C

STRUCTURED WARM-UP PRIOR TO ONE MILE

1) ***50 min prior to mile start:*** begin 18 minute warm-up jog
2) ***30 min – 20 min prior:*** static stretching of personal choice
3) ***20 min – 10 min prior:*** dynamic drills of personal choice
4) ***10 min prior:*** put on Polar HR monitors
5) ***10 min – 5 min prior:*** put on racing spikes/flats and REST
6) ***5 min prior:*** blood lactate & HR reading
7) ***5 min – start:*** final strides of personal choice

***Note: The purpose of this is to ensure a proper warm-up is completed for injury prevention, create good test re-test reliability and external validity. Also, this will create a parallel baseline in which the caffeine is absorbed in each of the participants. This warm-up is standard for Adams State University mid-distance athletes.*

APPENDIX D

STRUCTURED RECOVERY PERIOD BETWEEN MILE AND 400-METER BOUTS

1) ***0 – 6 min post mile:*** light walking, get water, remove racing spikes/flats during down time between gathering of RPE, HR, and LT
2) ***6 – 21 min post mile:*** 15 minute light recovery jog on tracks inner turf
3) ***21- 25 min post mile:*** light walking, water, put on racing spikes/flats, and REST
4) ***25 min post mile:*** gather HR and LT
5) ***25 – 30min post mile(start of 400-m):*** final strides or drills of personal choice

***Note: The purpose of this recovery period is creating parallel lactate clearance between all the participants. This specific timing also provides good test re-test reliability. This recovery period is similar to Adams State University's mid-distance athlete's recovery procedure.*